Stainless Steels for Application in Automotive and Transport Sectors

Over the last decade average weight of mid size car has reduced from 1400Kg to 1150Kg resulting in reduction of 18% of total car weight. Similar trend is also witnessed across all segments of passenger car. This was possible due to implementation of High Strength Steel (HSS) and Advanced High Strength Steel (AHSS) in automotive body structures. Mounting energy crisis, stringent emission law and strict safety rules have guided car manufacturers to improve strength/weight ratio of the vehicle, thereby promoting application of HSS and AHSS steels in the car body.

Automotive and Transport sectors are making increasing use of stainless steels to reduce weight, improve aesthetics, enhance safety and minimize life cycle cost. Characterized by superior fire and corrosion resistance, they ensure safety and reliability. Since stainless steels exhibit superior combination of high strength, ductility, formability and toughness compared to other metals and alloys, the intrinsic weight of vehicle decreases and its load carrying capacity and fuel efficiency increases. Maintenance cost is naturally lower and stainless steel component at the end of its long life is easily recycled.

In automobiles, stainless steels are most extensively used for exhaust systems. To improve efficiency, the designs for these components are becoming very complex and performance criteria are getting tougher. Since corrosion resistance remains vital for this application, appropriate titanium, niobium or dual stabilized grades with very low interstitial content are used with choice of grade depending on operating conditions.

Buses, trams make extensive use of austenitic stainless steels for outer panels. On account of transformation induced plasticity, these steels develop very high strength coupled with good formability in cold rolled tempers and constitute ideal material for structural components. The exceptional strength to weight ratio and energy absorption capacity enables the designers to reduce weight and enhance crash worthiness while ensuring longer life span due to superior corrosion resistance.

As new austenitic, ferritic and duplex stainless steels are evolving, automotive and transport industry is intensively exploring their potential.

Automotive Advanced Steels:

One of the important tasks for the 21st century is the maintaining of sound ecology. The reduction of the burden on the environment is an inevitable task assigned to industry. A direct contribution of the steel industry to the reduction of fuel consumption is the supply of steels enabling the lightening of automotive weight. There is a direct correlation between kerb weight of vehicle and fuel consumption. As a thumb rule, 10% of weight reduction will lead to 3%-7% less of fuel consumption. To reduce the weight of the vehicle and thus energy consumption, the usage of high strength steel in auto-making is gradually increasing. Figure 1 shows the diagram representing the materials used for manufacturing cars. The trend showing that there is increase in kerb weight in the year 2000, this is due to implementation of stringent safety laws. Following that there is decrease in kerb weight. This weight reduction was possible by development of HSS and AHSS and stringent environment law.

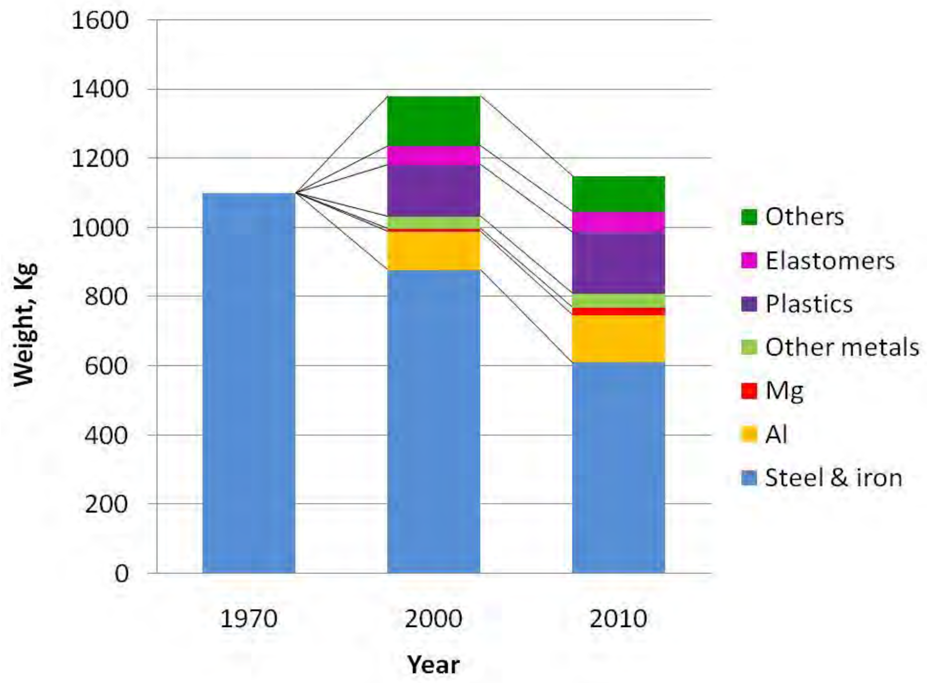

Figure 1: Materials used for manufacturing cars

Ferritic Stainless Steel in Automobiles

Interstitial free ferritic stainless steels with stabilization elements like Titanium, Niobium or a combination of both are extensively being used in parts of automotive exhaust systems such as manifolds, exhaust pipes, mufflers, catalytic converters etc. In this field of application for higher efficiency, the designs are becoming more complex and performance criteria are continuously increasing. Several different grades have therefore been developed (Table: 1) for applications at appropriate locations depending on operating condition (Figure: 2).

Table 1 Typical Composition of Automotive Stainless Steels

GRADE	%C	%N	%Cr	%Mo	%Ti	%Nb
409L	0.01	0.01	11	-	~0.2	-
432	0.01	0.01	17	0.5	-	~0.2
436L	0.01	0.01	16	1	~0.3	-
439	0.01	0.01	17	-	~0.4	-
441	0.01	0.01	17.5	-	~0.15	~0.35

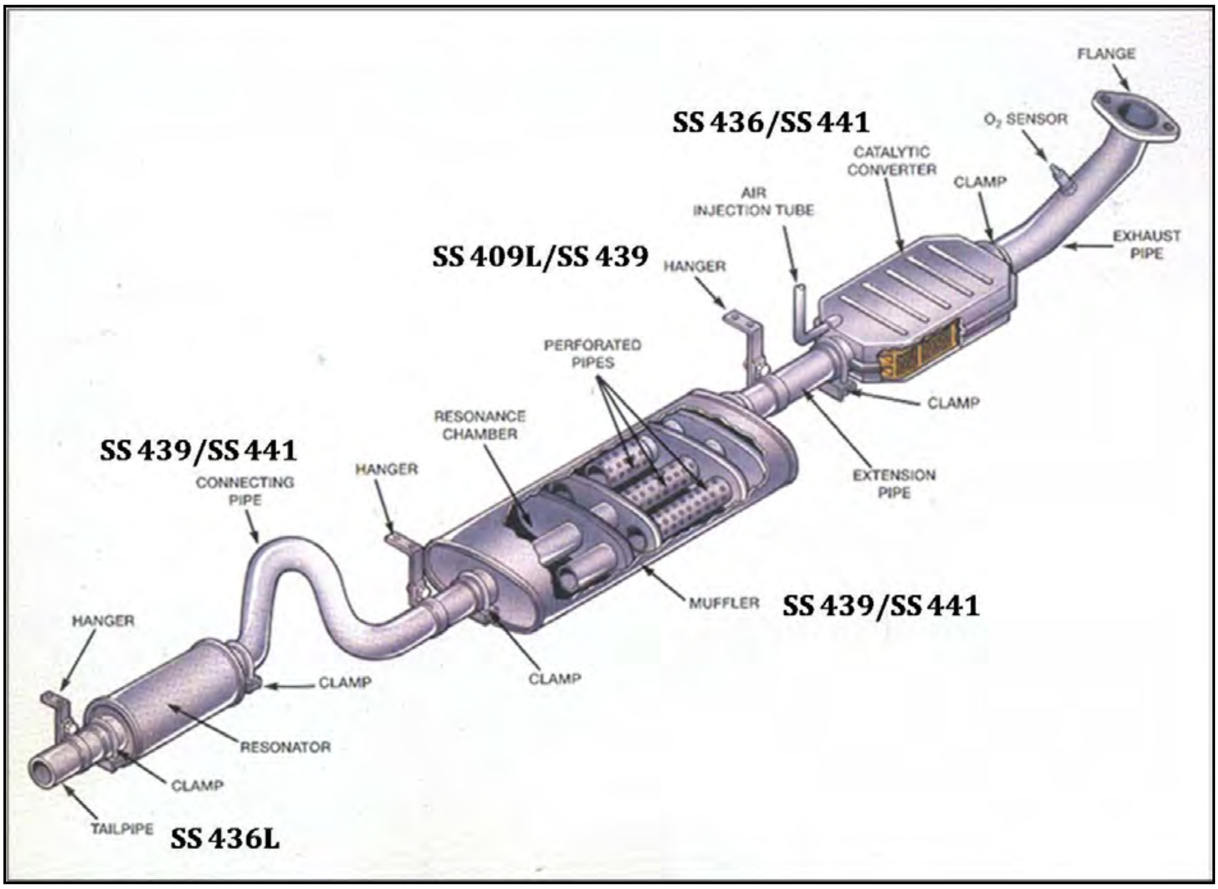

Figure 2: Automotive Exhaust System

Corrosion mechanism in the hot part of the exhaust system is oxidation and in the cold part due to intermittent condensation of exhaust gases – wet and dry corrosion. Oxidation resistance of various grades is shown in Figure: 3.

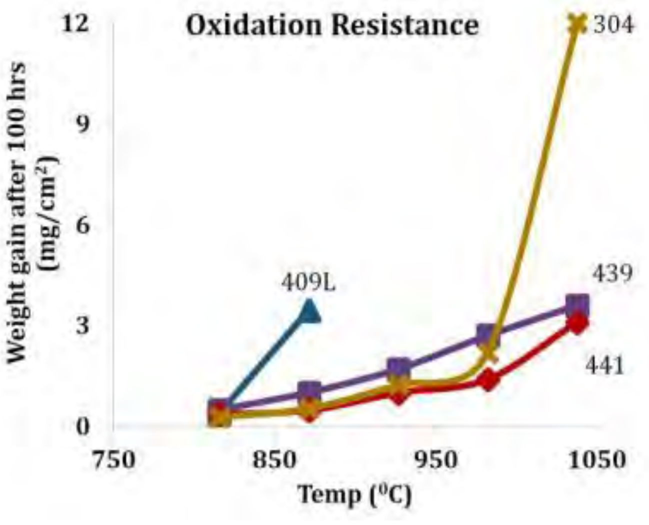

Figure 3: Weight gain in 100 Hrs of Oxidation in still air at elevated temperatures

In order to simulate internal corrosion mechanism of exhaust system environment, Dip-Dry test is done. The following graph in Figure 4 allows us to compare grades and thus to improve grade selection depending upon requirements.

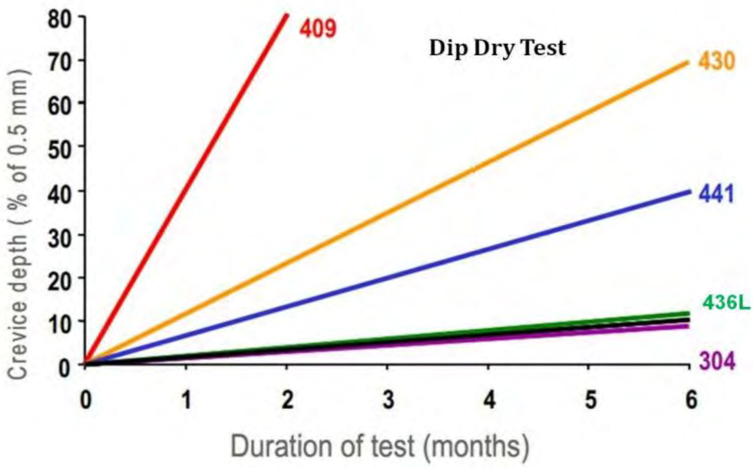

Figure 4: Dip Dry Test

In components subjected to elevated temperature, creep deformation can occur. Creep- Sag test is a rough but simple method to evaluate creep behavior of a grade compared to uni-axial creep to rupture or creep to deformation tests. Creep deflection on 1.5 mm thick specimens at 850°C, 950°C & 1000°C for 100 hrs are shown in Figure 5

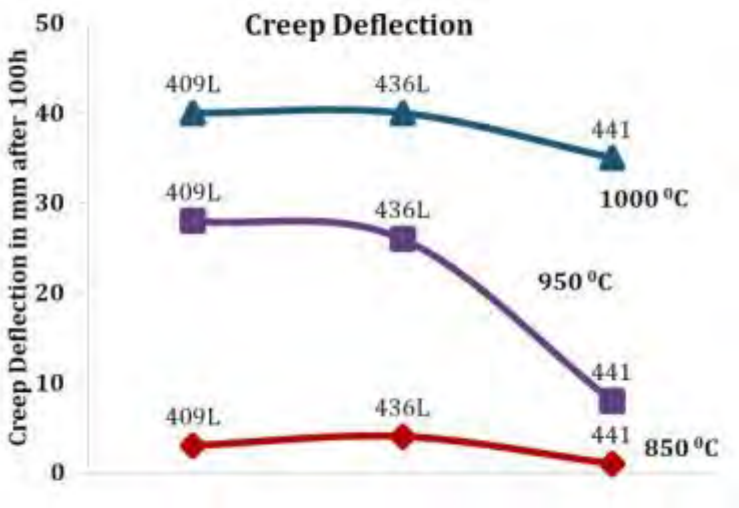

Figure 5: Creep Deflection at different temperatures.

Austenitic (Cr-Mn) Stainless Steel:

Nickel free Chrome-Manganese Stainless steel JSLT (Table: 2) has been successfully tested at Ashok Leyland for making of bumper that was previously being made from EDD steel (Extra deep drawing carbon steel). JSLT sheet of 1.2 mm thickness has successfully replaced 3 mm EDD steel (Figure 6) thus providing cost and material savings.

Table 2 Typical Chemical Composition of JSLT

Grade	C	Cr	Mn	Cu	N
JSLT	0.1 max	15.0-16.0	9.5-10.5	1.5-2.0	0.1-0.25
Typical composition	0.098	15.2	10.2	1.8	0.17

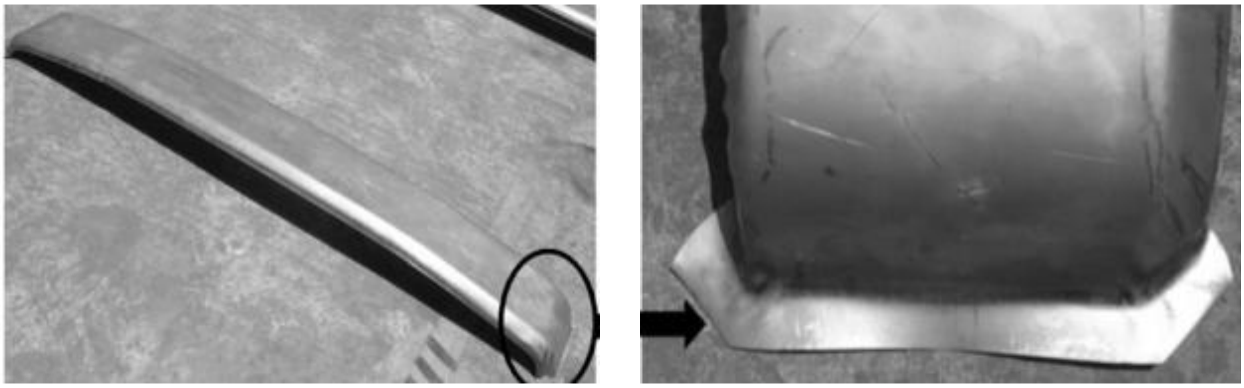

Figure 6: Bumper made of JSLT

This grade has good potential for other applications as well:

- Frame, load bearing floor panels, reinforcements
- Sheet metal cabin components, body panels, A- & B-pillar, all over beam
- Fuel tanks
- Wheels, suspension arm, gear shafts, propeller shafts

Stainless Steel in Ultralight Urban Bus:

Cold worked Cr-Mn Stainless steel such as Nitronic 30 (15Cr-1.5Ni-8Mn- 0.18N) is now being used for manufacture of full size urban transit buses (Figure 7a & 7b). This has resulted in a bus having a gross vehicle weight of 11 Tons which is less than half of a conventional transit bus (Figure 8 – Ultra-light Stainless Steel Urban Bus Concept - J. Bruce Emmons and Leonard J. Blessing Autokinetics Inc - SAE TECHNICAL PAPER SERIES - 2001-01-2073).

Table 3 Specified Mechanical Properties for Ultra-Light bus

	Y.S (in MPa)	% Elong.
Cold Rolled Stainless steel	800	25

Figure 7a

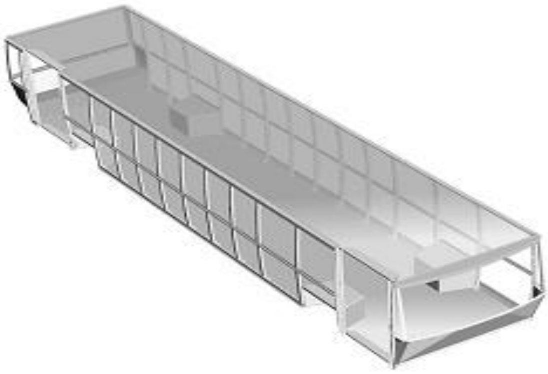

Figure 7b

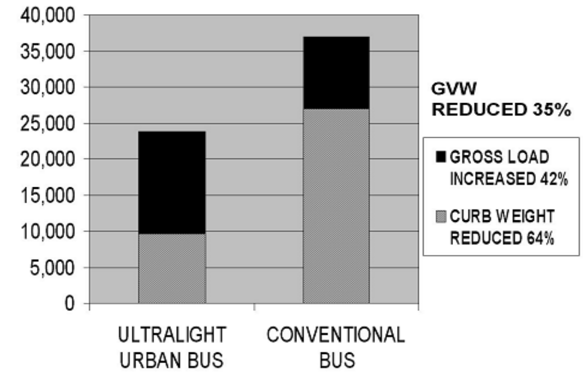

Figure 8

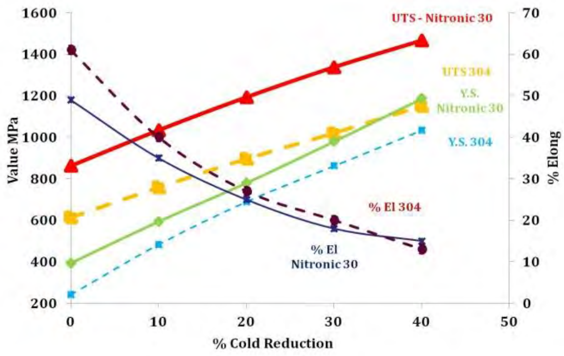

Figure 9

Due to the reduction in weight, 40% more passengers can be carried on the same bus. Such Cr-Mn-N stainless steels combine very high strength with high ductility (Figure 9) on account of transformation induced plasticity & their low electrical and thermal conductivity renders them highly suitable for spot welding.

Use of cold worked high strength Cr-Mn-N stainless steel coupled with manufacturing process such as roll forming and spot welding has led to reduction in cost of bus structure made up of such stainless steel to two-thirds of the cost of conventional steel bus (Bus Structure manufacturing cost - SYSTEM OPTIMIZATION OF AN ULTRALIGHT ELECTRIC TRANSIT BUS - Bruce Emmons, Autokinetics – April 20, 2006).

Future scope of High Nitrogen Cr-Mn Austenitic Stainless Steel has been shown in figure 10 below:

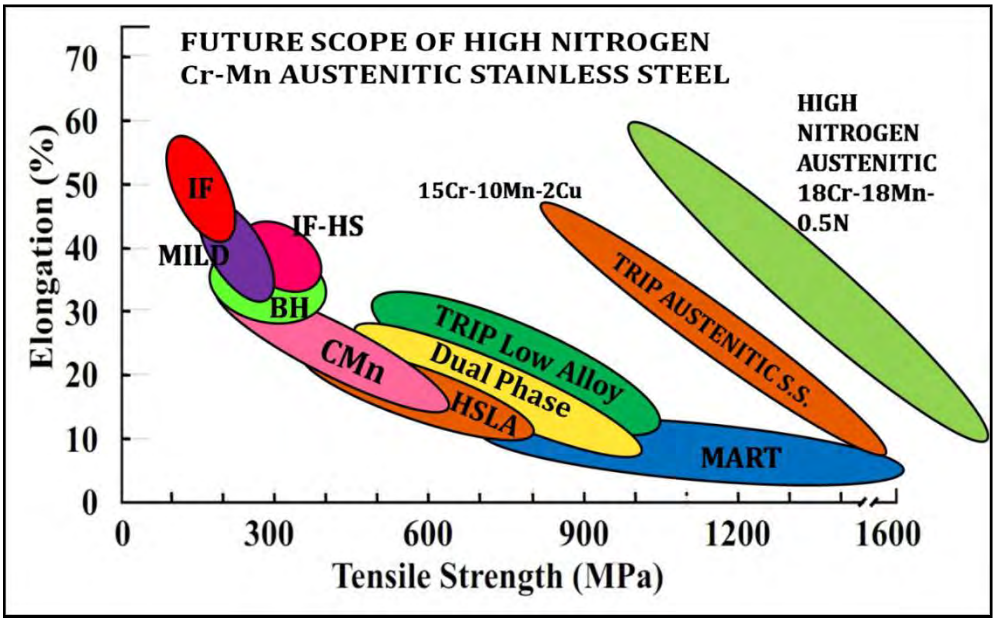

Figure 10 Future scope of High Nitrogen Cr-Mn Austenitic Stainless Steel

Another Cr-Mn-N grade, 204Cu (16Cr-1.5Ni-7Mn-2Cu-0.18N) has been extensively tested by recently completed European Union funded ECSC/RCFS research projects namely "*Stainless Steel in bus constructions*" & *"Development of light weight train and metro cars by using ultra high* *strength stainless steel"* in various transport sectors of Helsinki, Rome, Bay of Gibraltor & Madrid (Table: 4).

Table 4: 16Cr-7Mn in different transport sectors

LOCATION	CLIMATE TYPE	VEHICLE TYPE	TEST DURATION (MONTHS)	TOTAL DISTANCE (KMS)
HELSINKI	Urban with de-icing salt	Bus	23	87,040
ROME	Urban inland	Bus	18	42,011
BAY OF GIBRALTOR	Marine	Bus	21	59,320
SPAIN (MADRID)	Urban inland	Coach	19	105,395

Welding performance (Spot as well as Plasma Arc welding) was tested in above locations and different climatic conditions and comparisons were done with other stainless steel grades such as 304 and X2CrNi12. Discoloration (corrosion) of the base metal as well as welded portion was carefully monitored to determine cost effective material for buses and coaches.

204Cu fared far better than X2CrNi12 and behaved similar to 304 in both base materials as well as in welded portion in most of the conditions.