CHARACTERIZATION OF LOCALLY PRODUCED MARTENSITIC STAINLESS STEEL SURGICAL GRADE AISI 420A

By

Muhammad Kamran, Faraz Hussain, Taqi Zahid Butt, Fahad Riaz*

Abstract
The Martensitic stainless steel surgical grade AISI 420A is one of the major alloys being used in the production of surgical instruments in Pakistan. Till today, this alloy is being imported from Japan and France. Recently this grade has been developed in Pakistan. In this study this locally produced Martensitic stainless steel surgical grade AISI 420A was investigated. The sheet samples were tested for their composition, heat treated by austenizing at 1000 + 20°C, quenched in N_2 gas followed by tempering at 200°C and finally tested for their mechanical properties. It was observed that chemical composition fall within the standard composition with minor changes. It was also observed that hardness and tensile properties are within range.

Introduction
Pakistan is one of the largest countries producing and supplying surgical instruments all over the world. Tonnages of raw material are required for the production purposes. Surgical industry of Pakistan holds a history of more than 100 years, when some British doctors got their surgical instruments repaired from the skilled workers of Sialkot and that was the foundation of Sialkot surgical industry. **[1]**

Surgical Instruments Manufacturers Association of Pakistan (SIMAP) was established during 1958 with an aim to help solving the problems of surgical community. Surgical association has more than 2300 members till date, who are grossly engaged in manufacturing of surgical instruments to meet their export commitments in the International Market. The value of exports of surgical instruments for the financial year 2007-2008 was US $255 Million. **[1]**

Surgical stainless steel is a specific type of stainless steel, used in medical applications. The chromium gives the metal its scratch-resistance and corrosion resistance. The nickel provides a smooth and polished finish. The molybdenum gives greater hardness and helps maintaining a cutting edge. The word 'surgical' refers to the fact that these types of steel are well-suited for making surgical instruments: they are easy to clean and sterilize, strong and corrosion-resistant. The nickel/chromium/molybdenum alloys are also used for orthopedic implants as aids in bone repair, as a structural part of artificial heart valves and other implants. Immune system reaction to nickel is a potential complication. In some cases today titanium instead in procedures that require a metal implant which will be permanent. Most surgical equipment is made out of martensitic steel – it is much harder than austenitic steel and easier to keep sharp. Depending on the type of equipment, the alloy recipe is varied slightly to get more sharpness or strength. **[2,3,4]**

Typical compositions cover 12 to 18 Cr and 0.1 to 1.2 wt%. As with other martensitic steels, a balance must be sought between hardness and toughness. An untempered martensitic structure typically is strong but lacks toughness and ductility to an extent which depends on the carbon concentration. As a consequence, the martensite is in many cases tempered between 600 and 750°C to optimize the mechanical properties. **[2,3,5]**

In addition to the standard grades, a large number of alloyed martensisitc stainless steels have been developed for moderately high temperature applications. Most common additions include Mo, V and Nb. These lead to a complex precipitation sequence. A small amount (up to 2 wt%) of Ni is added to improve the toughness. **[2,3,5]**

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*Department of Metallurgy & Materials Engineering, CEET, University of the Punjab, Lahore.

Experimental Work
The sheet of locally produced martensitic stainless steel surgical grade AISI 420A was selected in this procedure in this present research work.

Chemical Analysis
The chemical analysis of annealed samples was carried out at Shalimar Steel Mill Lahore by using Atomic Emission Spectrometer.

Heat Treatment
The cut samples were heat treated for hardening and tempering at Dr. Frigz International (Pvt) Limited Sialkot. The samples were hardened by heating in vacuum furnace with a 0.01 mbar pressure at 1000 + 20^{o}C for 1 hour and then quenched inside the furnace in N_2 gas with back filling pressure of 1 bar. The hardened samples were tempered in tempering furnace at 200^{o}C [3].

Hardness Testing
The hardened and tempered samples were tested for their hardness. The Rockwell and Brinell hardness testers were used to calculate the hardness. The Rockwell hardness test was carried out at C scale. The Brinell hardness was performed with the major load of 3000 Kg and hardened steel ball of 10 mm diameter for calculating the Brinell hardness number [6].

Tensile Testing
The tensile samples of hardened and tempered sheet were prepared according to the ASTM standard E8 [7] as shown in figure 1. Tensile test was carried out on tensometer with a strain rate of 0.003 mm/sec.

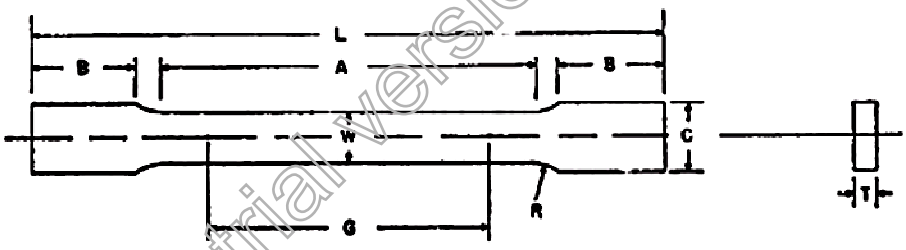

Figure 1: Tensile Specimen according to ASTM E08 [7]

Table1: Standard Dimensions of Tensile sample [7]

Gauge Length(G)	Width(W)	Thickness(Grip Section (c)	Length(L) (Overall)	Length (B) (Grip)
2 inch	0.5 inch	0.75 inch	8inch	2 inch

Results and Discussions
Chemical Composition
The chemical composition of locally produced Martensitic surgical grade AISI 420A obtained using Atomic Emission Spectrometer is given in the table 2. The standard composition reported in literature is also given in the table 2 for comparison [2,3]. It can be observed that the percentages of carbon and chromium, the major alloying elements, fall within the range. However the percentages of silicon, manganese and nickel are lower than the required. It was also observed the sulfur and phosphorous contents are also much lower than the upper limit. The lower content of Si, Mn and Ni may lower the final properties. **[6, 8,9]**

Table 2: Chemical Composition

Elements	%C	%Si	%Mn	%P	%S	%Cr	%Ni	%Mo	%Al
Standard	0.16-0.25	1.00	1.00	<0.040	<0.030	12.00-14.00	1.00	-	-
Locally produced	0.209	0.464	0.66	0.014	0.012	12.61	0.121	0.042	0.025

Hardness Testing

The hardness of the sheet samples both in the as-received and heat treated stage is given in the table 3. It can be observed that the Rockwell hardness of the as-received samples is somewhat higher than the standard which shows that the as-received sheet is not fully annealed. It can be observed that the Rockwell hardness value tremendously increased on heat treatment and approximately matches the standard one. The slight variation in hardness may be due to the change in temperature and time of holding both in austenizing and tempering and quenching rate. The Brinell hardness value also shows the similar trend.

Table 3: Hardness

Sample	Rockwell Hardness (HRc)		Brinell Hardness (HB)	
	Before Hardening	After Hardening	Before Hardening	After Hardening
Standard	0	52	-	-
Locally produced	10	46.75	80.5	145.80

Tensile Properties

The tensile properties of the as-received and after heat treatment are given in the table 4 and table 5. The mechanical properties clearly show that the yield stress and UTS has tremendously increased while the elongation was decreased as expected due to the heat treatment.

Table 4: Tensile Properties

Sample	As-Received		
	UTS (Kg/mm^2)	Elongation (%)	Yield Stress (Kg/mm^2)
Locally produced	84.3	14	68.10

Table 5: Tensile Properties

Sample	After Heat-Treatment		
	UTS (Kg/mm^2)	Elongation (%)	Yield Stress (Kg/mm^2)
Locally produced	157.48	7.40	129.10

Conclusion

1. The locally produced Martensitic stainless steel surgical grade AISI 420A sheet has approximately similar composition as of the standard, with slight variation in different alloying elements.

2. The hardness values are very much similar to the standard. The minor change in the hardness value may be due to the variation in the heat treatment parameters and composition.

3. The heat treatment showed a marked effect on the mechanical properties of Martensitic stainless steel surgical grade AISI 420A.

4. The locally produced Martensitic stainless steel surgical grade AISI 420A can be considered as a competitor for the imported one, where a slight variation in mechanical properties is acceptable.

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