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A COMPARATIVE STUDY OF MECHANICAL PROPERTIES AND MICROSTRUCTURES OF DEFORMED BARS (GRADE-60) LOCALLY MANUFACTURED IN PAKISTAN

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Abstract:

The MS deformed bars are widely used in construction, housing, bridges, flyovers, dams etc. And often the properties claimed by the industries may or may not be compatible with ASTM Standards. In order to check their compatibility with ASTM standards, MS deformed bar samples of Grade 60 of one inch (25 mm) diameter of five different companies were taken from open market. As One of Pakistan's popular examples of consistent business success has been the stainless steel and mild steel production. The hypothesis explored in this paper is that meeting such standards requires greater properties, both among producers as well as mechanical properties obtained by Tensometer and Universal Hydralic Tensile Machine. The study draws on qualitative data to examine either how much difference or similarity is drawn within samples of various industries. And these samples were coded as S-1, S-2, S-3, S-4 and S-5. First of all composition was determined by using Optical Spectrometer then Tensile performed at universal hydraulic Testing Machine and time load graphs were taken as this test is commercially used, and also Tensile was performed on Tensometer at laboratory level and Stress-Strain graph was obtained and calculated. It was

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concluded that the experimental results of most of the industries were in good agreement with ASTM but only a few did not show compatibility with ASTM standards.

1. Introduction.

Comprehensive knowledge of construction materials aids us in determining its exact behavior under service conditions. After fixing the raw materials used, method of manufacturing and compositional specifications, thermomechanical operations applied to steels play decisive role in formation of grain structure and deformation texture which in turn determine most of the mechanical properties of the material, majors include yield strength, ultimate tensile strength, Young's modulus of elasticity, Poisson's ratio and percentage elongation. Elaborated studies have been conducted to explore effects of process parameters on these properties within a certain range [1,2] which is defined by the composition of the steel. These parameters, besides other properties, also influence the flexural strength, under monotonic and cyclic loads, which if have adequate value makes steel a potential reinforcement material for seismic resistant structures [3]. Feasible recycling of obsolete steel structures makes mild steels best option emerging from their ease of formability combined with competitive price. Thermomechanical treatment (TMT) can successfully be applied to both plain carbon and alloy steels, former being more common due to simplicity and economics of the process, whereas the latter demands additional, sometimes prohibitive, accessories the plant should be equipped with and only adapted to achieve extra high strength in the products. Strain path and thermal treatment applied during rolling monitor the grain structure of the product thereby affecting the final static and dynamic properties of the same. In case of elongated grains, comparatively less number of slip systems is required for permanent set. On the other hand, in case of equiaxed grains, stresses required to actuate tensile behavior decrease with decreasing activated slip systems available [4,5]. Surface profile plays significant role in deciding behavior of steel member under service conditions. Any surface mark or imperfection may act as stress raiser leading to an immature failure. Numerous mathematical models have been proposed predicting the performance of the bar linked with stresses associated to the surface [6-8]. Purpose of steel reinforcement in concrete structure is manifold. Concrete offers excellent compressive strength but poor tensile properties which are substantially improved by reinforcing steel bars. Moreover, thermal expansion of plain carbon steels is quite similar to that of concrete up to moderately high temperatures. Deformed structure of steel provides stronger adhesion with concrete matrix. This work compares mechanical properties of steel deformed bars manufactured by various industries (in different process conditions such as hot rolled and thermo mechanically treated) with ASTM standards. It also highlights the claimed properties of various trademarks and actual properties calculated by metallurgical techniques.

2. Experimental work.

Five different specimens were taken from local industries of Lahore (Pakistan) which were then coded to S-1, S-2 S-3, S-4, and S-5 for professional reasons/ethics. The samples S-1,S-2,S-3,S-4,S-5 were taken from a lot of different heats according to the documentation presented in ASTM-A615 [9] for Tensile properties, hardness and microstructural analysis. Micrographs of specimens were recorded by Optical Microscope (Olympus GX 71). After fine polishing with diamond paste and etching with 2 % Nital, the microstructures were taken at Magnifications of 200X of specimens. For the purpose of tensile properties, Tensometer (M500-100 CT) and Universal Hydraulic Testing Machine (UHTM) (Exceed E64.206) at the strain rate of 5KN/min is used. Furthermore, Hardness was were measured on three scales of Vickers, Brinell and Rockwel by using universal hardness tester Identec (8187.5LKV).

3. Results and Discussion.

The conventional Metallographic techniques revealed the microstructures as normalized (Figure 1), S-4 has fine grain structure than others which have merely hot rolled and S-4 indicates its thermomechanical route resulting in greater strength, even possessing smaller carbon equivalent value than other specimens. Similar results has been observed while comparing S-3 and S-5, as S-3 has thermo mechanical treatment and other was received in hot rolled condition. ASTM A615 relies on a proper control of composition, also the steel samples be conformed with the recommended values of tensile strength, yield strength, and elongation as documented in the standard. Compositional dis agreement with ASTM A-615 specifications is being depicted in specimens S-1, S-3 and S-4 which are showing the various treatment history of specimens. While examining sample S-1 shows of Hardness 31 HRC as depicted in Table 1 is higher, also the yield stenght, U.T.S and ductility give increased values which do not agree with the ASTM A615 Standard (Table 2). Sample S-2 has a hardness of 16 HRC and is close to the requirements laid by ASTM A615 by showing yield strength of 541 MPA, UTS value of 843 MPA and a ductility of 10% (Figure 2 and 3). Considering Sample S-3 gives a reduced value of hardness as 10 HRC and a yield strength of 467 MPA, UTS of 650 and a ductility16%. This is by far the closest agreement with the ASTM A615 standard among the presented samples uptill S-3. S-4 has a hardness of 16 HRC and depicts a value of yield strength 676 MPA, UTS of 804 MPA and a ductility of 14%, these values again is not fully conformed with the standard. Sample S-5 shows a hardness value of 23 HRC and a yield strength of 447 MPA, UTS of 758 MPA and a ductility of 13%. As yield strength illustrated in table 2, it represents that S-1 is not as successfully subjected to TMT under optimum process parameters as S-3, despite having almost similar chemical compositions (Table 3). Hence through this study, it is recommended that the process treatment and post process treatment has vital importance to gain desired or commercially accepted properties.

Conclusion:

The experimental work was carried out for assessing the compatibility of commercial grade specimens with ASTM standards. In terms of yield strength, UTS and ductility the best comparison could be shown by S-3 and S-5. Only these specimens illustrated compatibility with ASTM A615, however, the best was S-5. In terms of composition, all specimens demonstrated compatibility with ASTM A615 but with a slight deviation as it could not be said they were in a 100% agreement. The claims made by industries are not realistic as none comply with the standards. Thermo mechanical treatment is an attractive proposition from economical view point, as comparable mechanical properties has been obtained with low alloying additions. Therefore, it can be deduced that TMT is better option when compositional check is of secondary importance.

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[9] ASTM Standard A-615, Full size, 2003a

Tables and Figures:

Table 1: The relevant hardness of specimens with respect to Vickers, Brinell and Rockwell Hardness scales.

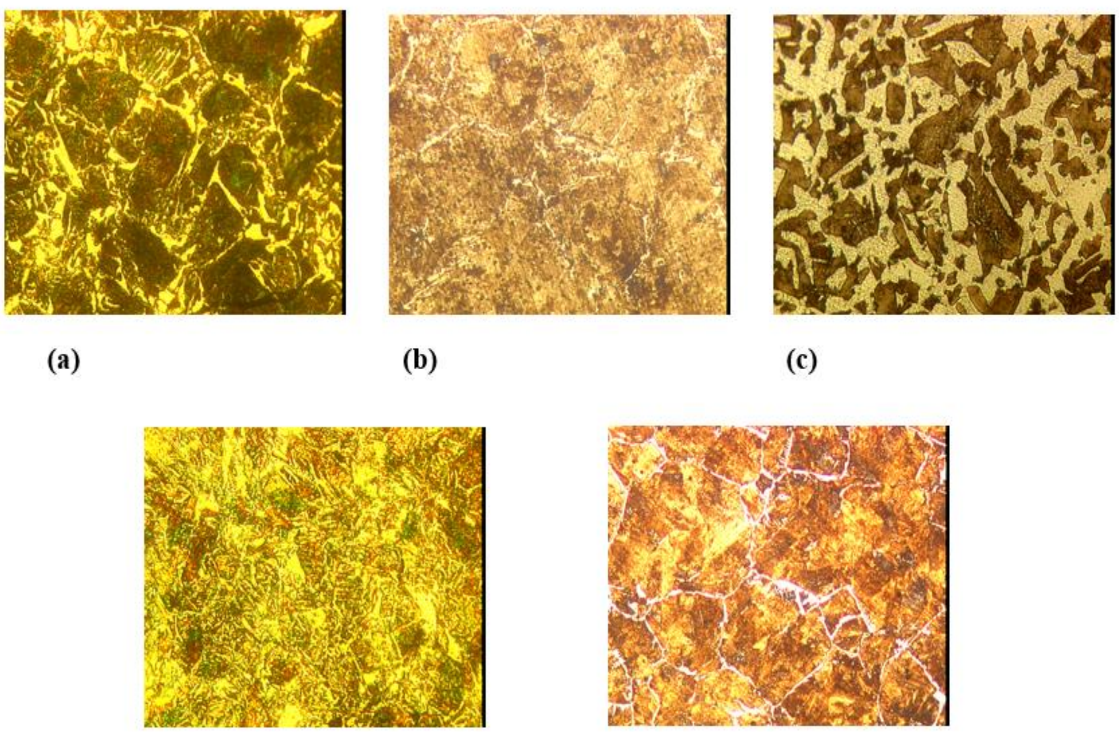
Sample I.D	V.H.N	B.H.N	R.H(HRC)
S-1	139	238.85	31
S-2	118	170.50	16
S-3	120	170.50	16
S-4	112	173.71	16
S-5	154	238.85	23

Table 2: The variation and comparison of Tensile properties of specimens and reading of Tensometer with those of Hydraulic Testing Machine.

Sample I.D	Yield Strength MPa		U.T.S MPa		Ductility %age	
	Tensometer	**U.H.T.M**	**Tensometer**	**U.H.T.M**	**Tensometer**	**U.H.T.M**
S-1	473.19	555.03	520	714.35	18	20
S-2	569.29	541	702.71	843.10	10	10
S-3	608.86	467.08	747.93	650.47	13	16
S-4	684.38	676.27	711.233	804.44	8	14
S-5	811.16	447.29	771.97	758.96	5	13
ASTM Value	**420**		**620**		**8**	

Table 3: The compositions of grade 60 specimens manufactured by various local suppliers against ASTM standard.

Sample ID	**C%**	**Mn%**	**P%**	**S%**	**Si%**
S-1	0.257	0.996	0.023	0.025	0.761
S-2	0.359	1.658	0.066	0.055	0.583
S-3	0.260	0.989	0.054	0.034	0.487
S-4	0.185	0.802	0.063	0.051	0.242
S-5	0.365	1.356	0.072	0.041	0.363
ASTM Values	**0.30-0.35**	**1.20-1.40**	**0.04**	**0.04**	**0.30**



(d) (e)

Figure 1 (a-e) Microstructures (Magnification at 200X- 2% Nital etched) of samples S-1, S-2, S-3, S-4 and S-5 respectively.

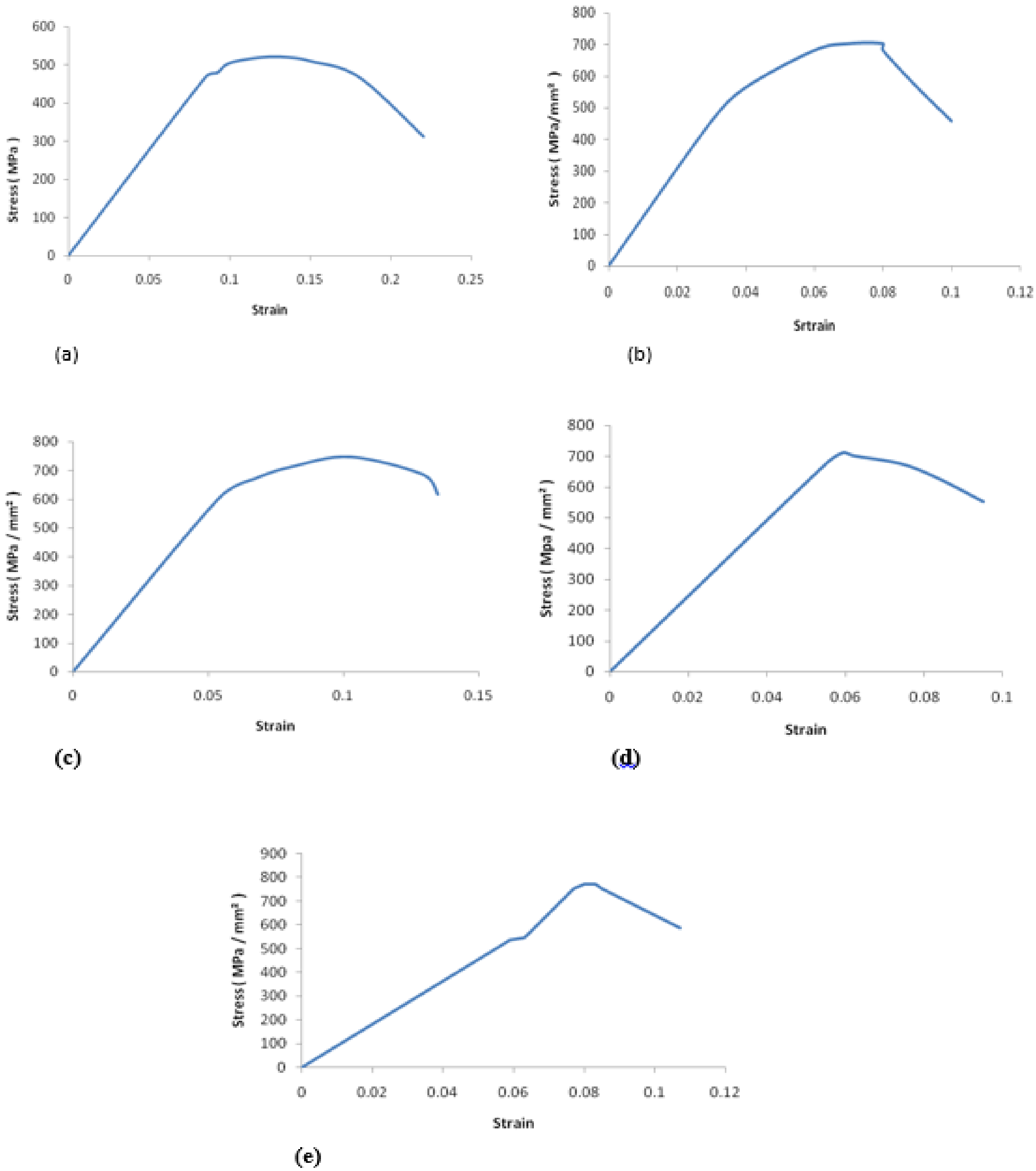


Figure 2 (a-e) Stress-Strain Curves of Samples S-1, S-2, S-3, S-4 and S-5 respectively by using Tensometer

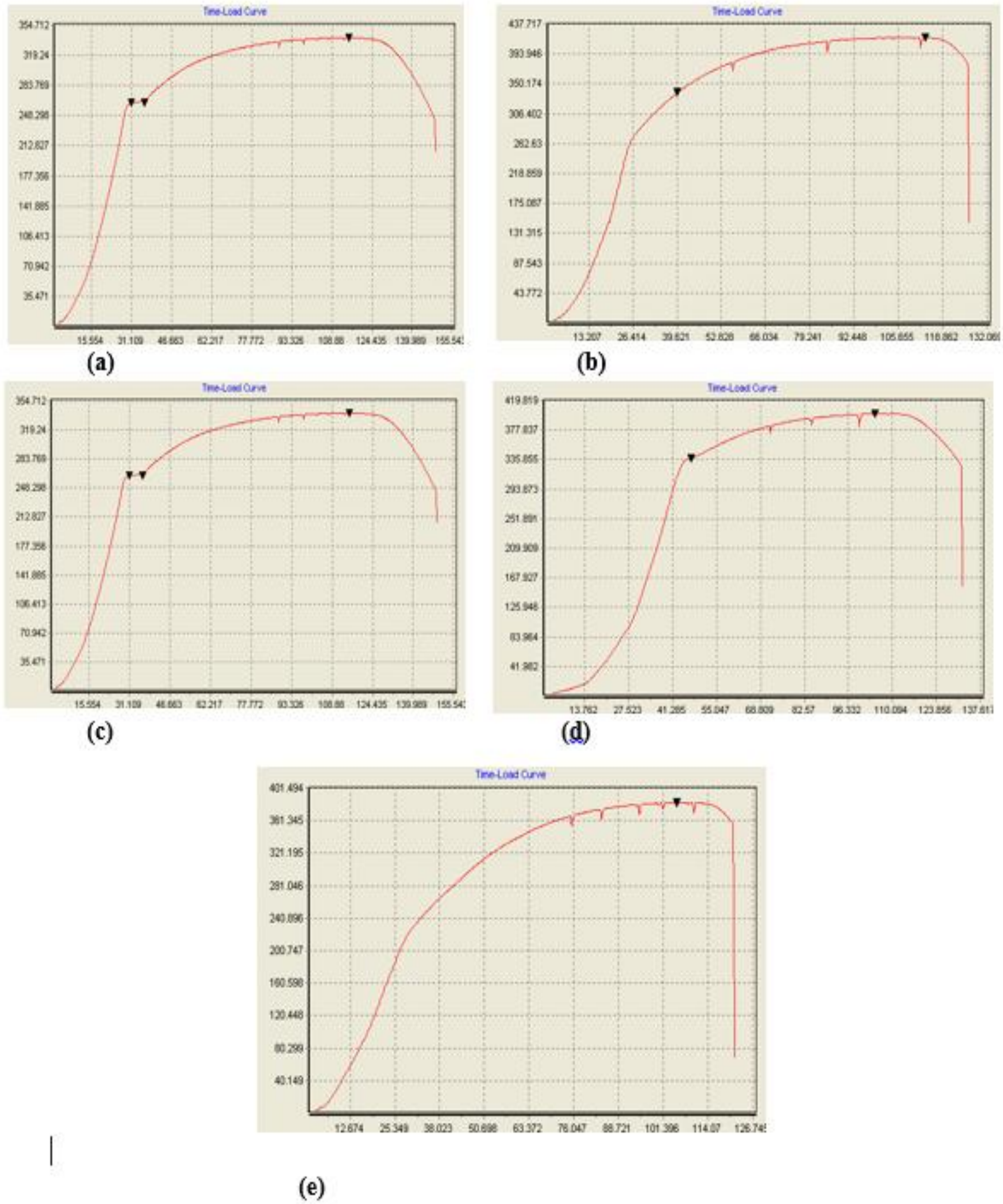


Figure 3 (a-e) Stress-Strain Curves of Samples S-1, S-2, S-3, S-4 and S-5 respectively by using UHTM