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Case study

Effects of rolling process parameters on the mechanical properties of hot-rolled St60Mn steel

Peter U. Nwachukwu*, Oluleke O. Oluwole

Department of Mechanical Engineering, University of Ibadan, Ibadan, Nigeria

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ABSTRACT

This work studied the effect of rolling process parameters at different rolling strain rates, % total deformations and finish rolling temperatures on the mechanical properties of hot-rolled St60Mn steel. The rolling process parameters studied included finish rolling temperature, % total deformation and rolling strain rates. The results were compared with existing literature on rolling carbon steels. The tensile strength, yield strength, hardness, young's modulus of elasticity, toughness, bendability, % enlongation and % reduction in area of the hot-rolled product were obtained. The results showed that the rolling process parameters remarkably influenced the mechanical properties of St60Mn steel. The trend in property change was dictated by rolling strain rate, % total deformation and finish rolling temperature.

It was concluded that increasing the rolling strain rate from 6.02851×10^3s-' to 6.10388×10^3s-', using % total deformations of 99% and finish rolling temperature of 958 °C enhanced the mechanical properties of St60Mn steel.

1. Introduction

It had be concluded so far that in hot rolling, increase in height of roll grooves which was a function of its expansion, caused by the process parameters, resulted in increase in thickness of rolled stock, which affected the mechanical properties of the rolled samples such as ultimate tensile strength, yield strength, bendability, modulus of elasticity, % reduction in area, hardness, toughness and % elongation, depending on the diameter of rebar being rolled.

Dutta stated that during hot-rolling, a metal billet or bloom/slab with a thickness h_i enters the rolls at the entrance plane x-x with a velocity v_i. It passes through the roll gap and leaves the exit plane y-y with a reduced thickness h_f and at a velocity v_f. Given that there is no increase in width, the vertical compression of the metal is translated into an elongation in the rolling direction. Since there is no change in metal volume at a given point per unit time throughout the process,

$$bh_iv_i = bhv = bh_fv_f$$

Where, b is the width of the metal stock, v is the velocity at any thickness h intermediate between h_I and h_f.

Obikwelu [2], in his study on the optimization of mechanical properties of rolled products, discovered that most mills in developing nations of the world still operated on the basis of conventional rolling which was devoid of modern facilities

* Corresponding author.
E-mail addresses: ebubedikeugwu@gmail.com (P.U. Nwachukwu), lekeoluwole@gmail.com (O.O. Oluwole).

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Table 1
Chemical composition of the material specimen used.

Steel grade	Chemical composition %								
	C	Si	Mn	P	S	Cr	Ni	Cu	N
ST60Mn	0.41	0.24	1.12	0.021	0.008	0.02	0.03	0.03	0.010

offered by controlled rolling. According to his findings, conventional mill operations were not executed along with the necessary temperature monitoring with a view to controlling the evolved microstructure.

Saroj [5] further stated that steel bars produced through conventional rolling often exhibited abysmally low mechanical properties. From their findings, control of inter-stand temperature such that the desired initial austenite grain size is achieved at the last stand is imperative. This would ensure that appropriate phase transformation of the right grain size, morphology and texture is obtained during cooling of the bars.

Table 2
Effects of rolling strain rates on the mechanical properties of St60Mn steel at constant finish rolling temperatures,changing % total deformations.

Sample ID	Rolling strain rate (S^{-1})	% Total deformation	Finish rolling temperature (°C)	Ultimate tensile strength (MPa)	Yield strength (MPa)	% Elongation	Toughness (J/mm^2)	Bendability	% Reduction in area	Hardness (HB)	Young's modulus of elasticity (GPa)
01	6.02851×10^3	99	922	612	445.3	18.6	0.4607	45.95	30.2	222	57
02	6.02851×10^3	98	922	569	425	19	0.5089	44.48	36	221	53
03	6.02851×10^3	96	922	509.5	423	19.5	0.5195	42.75	40	216	40
04	6.03713×10^3	99	922	614	450.5	18.4	0.4606	46	30	224	60
05	6.03713×10^3	98	922	569.6	426	18.7	0.5086	44.49	34.9	223	53
06	6.03713×10^3	96	922	511	424	19.2	0.519	42.78	39	217	40
07	6.06754×10^3	99	922	614.6	456.5	18.1	0.4605	46.05	29.8	229	61
08	6.06754×10^3	98	922	570	428.5	18.4	0.5076	44.5	34.5	224	53
09	6.06754×10^3	96	922	512.8	425	18.9	0.5185	42.9	39.9	218	42
10	6.07132×10^3	99	922	622	477	16	0.4605	46.25	26.8	229	61
11	6.07132×10^3	98	922	572.3	440	17.3	0.502	44.53	34.2	225	55
12	6.07132×10^3	96	922	520.1	429	17.7	0.5135	43.45	39.8	220	42
13	6.0981×10^3	99	922	629	479	15.7	0.4527	46.28	26.3	230	62
14	6.0981×10^3	98	922	580	443.3	16	0.501	45	34.1	226	55
15	6.0981×10^3	96	922	539	441	16.9	0.5127	43.52	39	221	44
16	6.10388×10^3	99	922	635.7	483	15.4	0.4525	46.34	26	231	65
17	6.10388×10^3	98	922	600	445	15.9	0.498	45.2	33.5	227	56
18	6.10388×10^3	96	922	598.6	443	16.3	0.512	43.6	37.8	222	44
19	6.02851×10^3	99	939	610	445	18.7	0.4608	44.93	30.3	221	56
20	6.02851×10^3	98	939	568	424	19.5	0.509	44.47	37	220	53
21	6.02851×10^3	96	939	509	421	19.9	0.5196	42,74	43	215	40
22	6.03713×10^3	99	939	613	448	18.5	0.4607	45	30.1	223	59
23	6.03713×10^3	98	939	570	425	18.8	0.5087	44.48	35	222	53
24	6.03713×10^3	96	939	510	423	19.4	0.5192	42.77	41	216	40
25	6.06754×10^3	99	939	614	456	18.2	0.4606	46.04	29.9	227	60
26	6.06754×10^3	98	939	572	428.4	18.5	0.5077	44.49	34.7	223	53
27	6.06754×10	96	939	512.7	424	19	0.5186	42.8	40	217	41
28	6.07132×10^3	99	939	621	464	17	0.4605	46.24	26.9	228	60
29	6.07132×10^3	98	939	579	436	17.4	0.503	44.52	34.3	224	54
30	6.07132×10^3	96	939	520	428	17.9	0.5136	43	39.9	219	41
31	6.0981×10^3	99	939	628	476	16.7	0.4528	46.27	26.5	229	61
32	6.0981×10^3	98	939	583	443.2	16.3	0.502	44.98	34.2	225	54
33	6.0981×10^3	96	939	538	440	17	0.5128	43.51	39	220	43
34	6.10388×10^3	99	939	634.7	480	16.4	0.4526	46.33	26	230	64
35	6.10388×10^3	98	939	598	444	16	0.499	45.1	33.8	226	55
36	6.10388×10^3	96	939	580	442	16.5	0.513	43.5	37.9	221	43
37	6.02851×10^3	99	958	508	443	19.4	0.461	44.91	30.8	220	55
38	6.02851×10^3	98	958	566	423	20.4	0.515	43.47	39	219	51
39	6.02851×10^3	96	958	507	419	21.2	0.5199	42.72	48	214	39
40	6.03713×10^3	99	958	611	446	19.1	0.4609	44	30.5	222	58
41	6.03713×10^3	98	958	568	424	19.6	0.5095	43.5	37	221	52
42	6.03713×10^3	96	958	505	420	20.5	0.5197	42.75	45	215	39
43	6.06754×10^3	99	958	613	454	18.9	0.4608	45	30	226	59
44	6.06754×10^3	98	958	570	427	19.4	0.5085	44.46	34.8	222	52
45	6.06754×10^3	96	958	511	422	20.2	0.5187	42.8	43	216	40
46	6.07132×10^3	99	958	620	463	18	0.4607	45.23	28.6	227	59
47	6.07132×10^3	98	958	577	435	18.6	0.5039	44.5	34.4	223	53
48	6.07132×10^3	96	958	518	425	19.8	0.5156	43	41.1	218	40
49	6.0981×10^3	99	958	626	475	17.7	0.453	46.24	26.6	228	60
50	6.0981×10^3	98	958	582	442	18.3	0.5029	44.90	34.3	224	53
51	6.0981×10^3	96	958	536	439	19.2	0.5135	43.49	40	219	43
52	6.10388×10^3	99	958	633	478	17.3	0.4528	46.3	26.1	229	63
53	6.10388×10^3	98	958	596	443	17.9	0.501	45	33.9	225	54
54	6.10388×10^3	96	958	570	441	18.6	0.5131	43.5	38.8	220	43