Trans. Indian Inst. Met.
Vol. 61, Nos. 2-3, April-June 2008, pp. 187-191

TP 2206

Studies On The Effect Of Ball Burnishing Parameters On Surface Hardness Of HSLA Dual-phase Steels Using Factorial Design

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(Received 21 November 2007 ; in revised form 6 December 2007)

ABSTRACT

Burnishing is used increasingly as a finishing operation which gives additional advantages such as increased hardness, fatigue strength and wear resistance. Experimental work based on 3^4 factorial design was carried out to establish the effects of ball burnishing parameters on the surface hardness of HSLA dual-phase steel specimens. Statistical analysis of the results shows that the speed, feed, lubricant and ball diameter have significant effect on surface hardness.

1. INTRODUCTION

Any investigation will be planned according to its objectives. This investigation too has few objectives, which can be categorized into two modules. The first is to develop dual phase microstructures containing volume fractions of martensite and ferrite, to be followed by determination of the optimum burnishing parameters in obtaining highest hardness on dual phase specimens.

The finishing of metals with a hardened surface layer has attracted the interest of researchers, e.g. those in the optomechanical industry. The functional performance of a component, such as fatigue life, load bearing capacity and wear, depends on its surface characteristics such as hardness, induced residual stresses and topography. Czichos and Habig[1] studied the tribological behavior of medium carbon steel. They found that different wear values, wear patterns and wear mechanisms result depending on various factors, material parameters (e.g. hardness), operating variables (e.g. kinematics), geometry of the tribological system, and interfacial conditions. Studies by Kudryavtsev[2] have established the beneficial effects of residual compressive stresses and work hardening in improving the fatigue strength of various materials. Burnishing, a plastic deformation process, is commonly used to achieve good surface finish. Unlike machining processes, burnishing was also found to give several additional desirable surface characteristics, i.e. higher fatigue strength, increased surface hardness due to work hardening, higher wear resistance, good corrosion resistance and good surface finish[3-12]. In order to utilize the increased hardness effectively of the burnishing process, the parameters affecting surface hardness have to be established. In this paper, a systematic study of the effects of ball burnishing parameters on the surface hardness of HSLA dual-phase steel specimens is reported. For the experiments to be performed efficiently, statistical techniques such as 3^4 factorial designs were used.

The global energy crisis has thrown open perpetual challenges to the materials technologists to evaluate newer materials with improved combinations of high strength, ductility and toughness. This led to the emergence of a series of composite microstructures, in which dual-phase (DP) steels represent a distinguished class. The specific potentials of dual-phase steels that have been technologically exploited are their superior ductility and formability characteristics compared to HSLA or conventional plain carbon steels of similar strength level The path of evolution of dual-phase steels has been reported by numerous investigators directed towards understanding the role of a large number of microstructural variables, which influence their mechanical properties.

Commonly, low carbon steels exhibiting ferrite (~80%) – martensite (~20%) microstructures are referred to as dual-phase steels; however these may contain small amounts of retained austenite and/or bainite depending on alloy content and processing parameters. The initial reports on DP steels can be traced back to the mid 1960's[13-14]. But only in the mid 1970's these steels become of technological interest because of their attractive combinations of superior strength and formability properties over the conventional high strength low alloy steels (HSLA) particularly for applications in weight saving engineering components.

The intense interest centered on the development of ferrite-martensite dual-phase steels has led to numerous investigations. The content of such reports can be broadly classified into 2 groups:-

(i) Physical metallurgy aspects of dual-phase steels; which incorporate information and understanding related to the evolution of dual-phase microstructures, the effects of various alloying elements on microstructure development, and the studies related to the kinetics of formation and nature of individual phases involved during phase transformation, and

(ii) Structure property relations in dual-phase steels; which include the attempts to search for correlations between the nature, volume fraction, size, and distribution of ferrite, martensite, and retained austenite, on one hand, and the strength, ductility, work hardening rate, fatigue life, corrosion resistance, toughness properties, on the other hand.

2. EXPERIMENTAL WORK.

2.1 Material

Commercial micro-alloyed steel supplied by M/s Swedish Steel, [Oxelosund; Sweden] was selected as the starting material. The as- received steel was in the form of 20mm thick hot rolled plate in the tempered condition. The chemical composition of steel was ascertained with the help of **Baird optical emission spectrometer.** The analyzed composition of steel was found to be in agreement with the suppliers' certification as shown in Tables 1& 2.

2.2 Heat treatment

The dual-phase microstructures were prepared by intermediate quenching (IQ). The IQ-treatment consisted of a double quench operation. The specimens were first soaked at 920+2 deg C for 30 min and were quenched in 9% iced-brine solution (-7ºC). These were then held at different inter critical temperature (ICT) of 750°C for 60 min and were finally quenched in oil (25 ± 2°C) which is shown in Fig. 1.

2.3 Microstructural characterization

Several stereological measurements were carried out to estimate the volume fraction of ferrite and martensite in the developed microstructures using manual point counting technique and automatic areal analysis using a LECO image analyzer.

2.4 Factorial design

There are numerous advantages associated with the use of factorial design in the conducting of experiments: it is more efficient than the conventional one-factor-at-a-time experiments commonly employed by researchers, and also enables the study of both the main and interaction effects between factors. Further, should a parameter (eg. Surface hardness) needs to be minimized (or maximized) with respect to a combination of factors, factorial design will give a combination near to the minimum (or maximum), whereas the one-factor-at-a-time procedure will not.

In the 3^4 factorial design used, four factors (burnishing parameters) were studied. The four factors selected were: ball diameter, lubricant, feed and speed. Each quantitative and qualitative factor has three numerical values and three types of material respectively, commonly known as three "levels". The four factors and their respective levels are shown in Table 3.

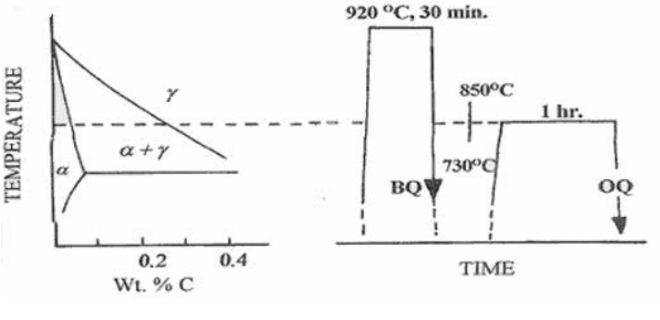

Fig. 1 : Intermediate quench

Table 1

Chemical composition (wt%) of HSLA steel

S.No	Chemical Composition	Weight %
1	C	0.15
2	Si	0.27
3	Mn	1.24
4	S	0.004
5	P	0.009
6	Cr	0.05
7	Mo	0.03
8	B	0.0012
9	Nb	0.022

Table 2

Results of volume fractions of ferrite and martensite

S.No.	Specimen	Specimen Temperature	Volume %
1	Ferrite	750º C	59.8
2	Martensite	750º C	40.2

Table 3

Experimental burnishing factors and levels

S.No	Burnishing Factors	Specifications
1	Ball diameter	12.5mm
		13.5mm
		16.5mm
2	Lubricant	Grease (Servo make)
		Kerosene
		Mixed lubricant (Water+Coolant Oil)
3	Feed	0.07mm/rev
		0.08 mm/rev
		0.09 mm/rev
4	Speed	22. 62m/min
		33. 93m/min
		56. 56m/min

The experimental work was conducted on Kirloskar Turn Master lathe machine. The ball-burnishing tool shown in Fig. 2 is the main element in the burnishing process. It accommodates carbon chromium Steel ball of various diameters. The burnishing tool was held stationary and rigidly on the tool post of the lathe machine.The feed terminology

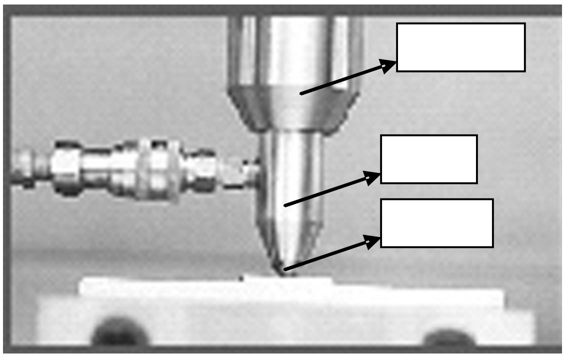

Fig. 2 : Ball burnishing tool assembly

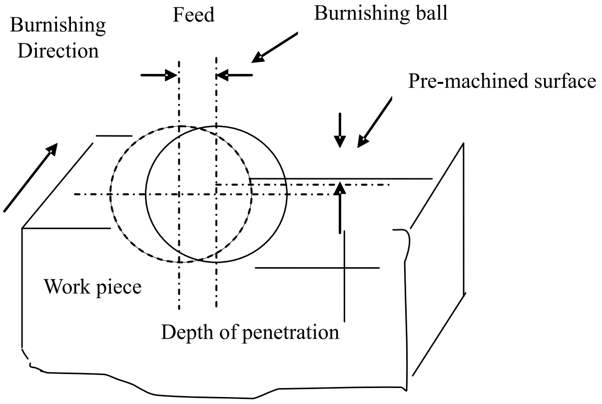

Fig. 3 : Schematic illustration of terminologies.

is shown in Fig. 3, which is the horizontal distance between two successive ball centers.

The work pieces were selected as cylindrical bar of 18 mm diameter. The bars were cut to appropriate length 250 mm and each were divided into 8-10 segments. Each segment was taken a length of 20mm width by making grooves in between each segment with the intent of exposing to different set of conditions during the experiment. The hardness of the pre-machined and burnished surfaces was measured using Vickers hardness equipment. A pyramid diamond indentor with 136 degrees apex angle was used and indentation load of 200gf for 10 sec was applied.

3. RESULTS AND DISCUSSION

Experimental results for hardness values comprising all possible burnishing conditions are shown in Table 4 for different volume percentages of ferrite and martensite.

3.1 Effect of ball diameter

The surface hardness of burnished specimen is dependent on the ball diameter. It is evident from the experimental results shown in Table 4. The ball diameter of 16.5mm diameter gives the highest hardness value, which is about 60% higher than the pre-machined surface hardness. Under the same burnishing conditions, the balls with different diameters give different surface hardness values (see Figs. 4-6).

3.2 Effect of lubricant

The application of lubricant has significant effect on any metal cutting and metal forming process. It will reduce the force of cutting and forming by reducing the friction conditions in those processes. In burnishing also, lubricants will assist in easy deforming of surface layer with applied feed and speed. From the experimental results the effect of lubricant on surface hardness is significant. Under the burnishing conditions, burnishing with grease gives higher hardness than kerosene and mixed lubricant.

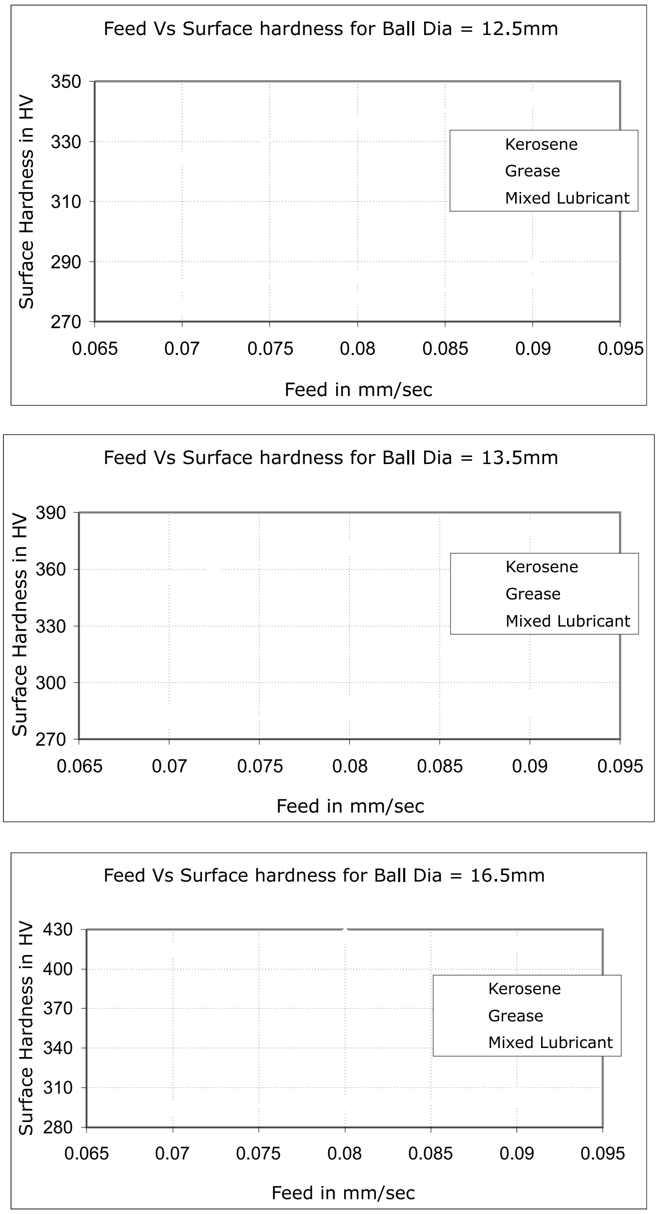

Fig. 4 : Relationship between Feed and Surface hardness for 22.62 m/min speed

3.3 Effect of speed

The effect of speed of the specimen on surface hardness is significant .The optimum speed is found from the table 4 is 22.62m/min.

3.4 Effect of feed

The work hardening effect on the burnished surface is greater at lower feed and decreases with increase in feed. This is so, since at lower feed the number of times a ball deforms over the same spot is greater than at higher feed. Thus at lower

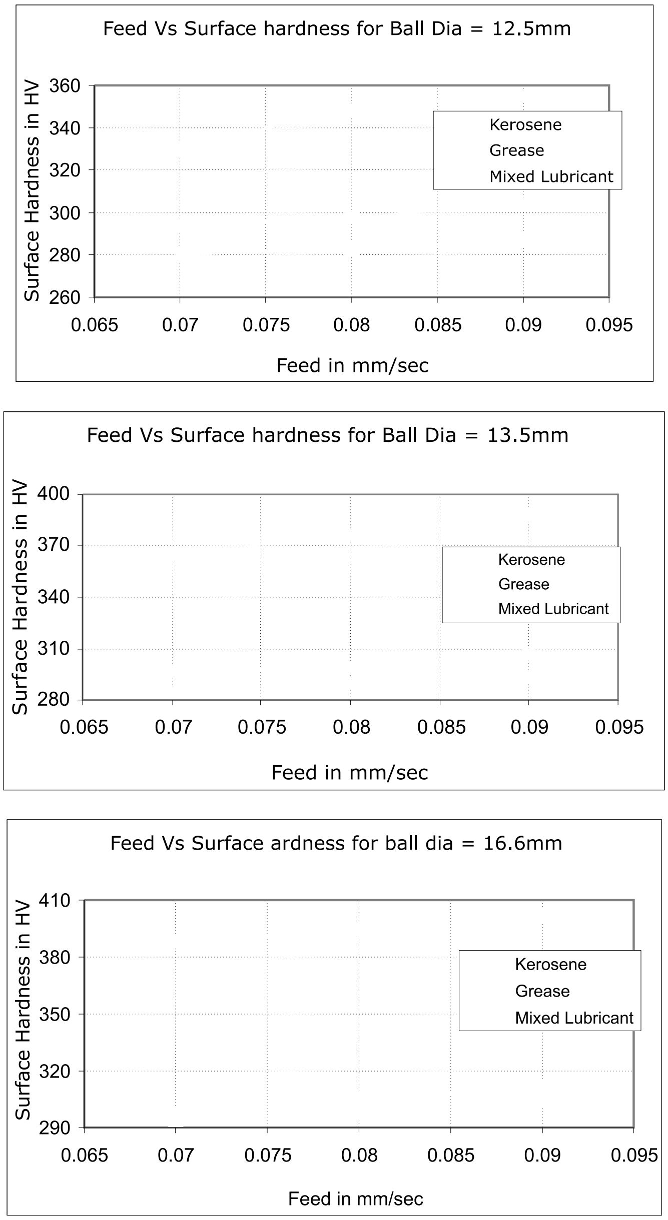

Fig. 5 : Relationship between Feed and Surface hardness for 33.93m/min speed

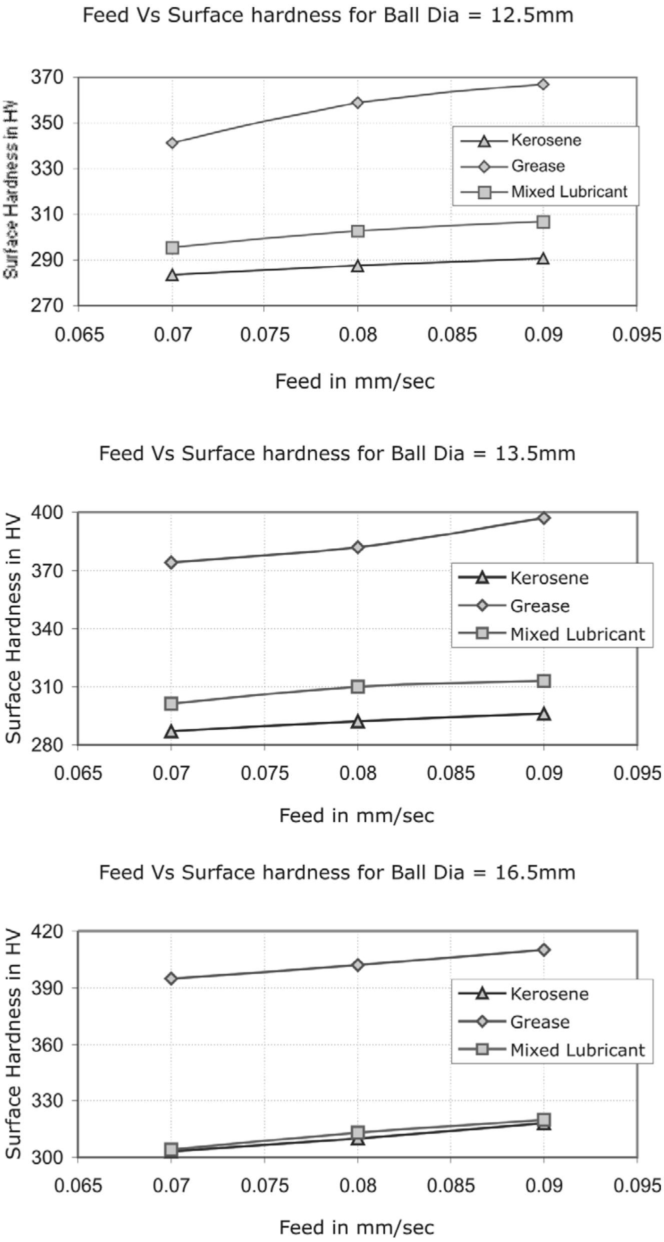

Fig. 6 : Relationship between Feed and Surface hardness for 56.56 m/min speed

Table 4

Volume % of ferrite =59.82, volume % of martensite = 40.18 and inter critical temperature = 750°C, Pre-machined surface hardness = 268 HV.

Speed m/min	Feed mm/rev	Ball dia = 12.5 mm			Ball dia = 13.5 mm			Ball dia = 16.5 mm		
		Kerosene	Grease	Mixed Lubricant	Kerosene	Grease	Mixed Lubricant	Kerosene	Grease	Mixed Lubricant
22.62	0.07	275	324	282	279	356	284	293	414	294
	0.08	278	336	285	284	371	289	297	426	299
	0.09	283	344	289	286	382	293	301	419	305
33.93	0.07	280	330	294	284	365	296	294	388	297
	0.08	283	348	298	289	376	300	298	394	305
	0.09	287	355	304	293	388	307	304	402	311
56.56	0.07	284	341	296	287	374	301	303	395	304
	0.08	288	359	303	292	382	310	310	402	313
	0.09	291	367	307	296	397	313	318	410	320

feed the plastic deformation is more intensive, causing a greater increase in surface hardness. It is evident from the experimental results that the surface hardness increases with an increase in feed.

4. CONCLUSIONS

The effect of ball diameter, speed, feed and lubricant on surface hardness of HSLA dual-phase Steels were studied. The main results obtained are as follows

- Optimum burnishing parameters on dual-phase steels were established and these can be used for maximum benefit of burnishing process.
- It can be concluded from the experimental results that highest surface hardness can be achieved by 16.5mm diameter ball, grease as lubricant, feed of 0.08 mm/rev and speed of 22.62 m/min.
- Experimental work shows that an improvement of about 55% - 60% in surface hardness of dual- phase Steels can be obtained by ball burnishing process.

ACKNOWLEDGEMENTS

The authors would like to thank Sri. D.B. Prakash and Sri. Shiva Kumar of Material Science Laboratories (R&D Division), M/S Bharath Earth Movers Limited, K.G.F Complex for supporting this experimental work on ball burnishing.

The authors acknowledge gratefully the contribution of D. Sujana, D. Hemanth, S.R. Mithun Kumar, Sri Arthur Davis, S. Andrew, Murali Krishna. R., Faculty of Mechanical Engineering, Golden Valley Institute of Technology, K.G.F.

REFERENCES

1. Czichos and Habig, Proc. JSLE Int. Tribology Conf., Tokyo, July 8-10, 1985, Elsevier, Amsterdam (1985) 879.
2. Kudryavtsev I V, *Russ. Eng. J.*, **50** (1970) 8.
3. Belov Y A, *J. Mach. Tool.* U.S.S.R., **34** (1963) 23.
4. Pande S S and Patel S M, *J. Mach. Tool Des. Res.*, **24** (1984) 195.
5. Loh N H, Tam S C and Miyazawa S, *Int. Jnl. Mech. Tools Manuf.,* **31**(1) (1991) 75.
6. Wagner L, Mueller C, *Materials & Manufacturing Proceses J* **7**(3) (1992) 423.
7. Lee S S G, Tam S C and Loh N H, *Jnl. of Materials Processing Tech..* **29** (1992) 203.
8. Lai M O, Nee A Y C and Oh J T, *Jnl. Of materials processing Tech.,* **29** (1992) 301.
9. Jack R. Clark and Marion B. Grant, *Jnl. Mech. Tools Manufact.* **32**(12) (1992) 57.
10. Lee S S G, Tam S C and Loh N H, *Jnl. Of Materials Processing Tech.,* **37** (1993) 241.
11. Loh N H, Tam S C and Miyazawa S, *Precision Engg.,* **15**(2) (1993) 100.
12. Loh N H, Tam S C and Miyazawa S, *Int. Jnl. Mech tools Manuf.,* **33**(6) (1993) 841.
13. Rashid M S, Vanitec, Berlin, (1978) 32.
14. Marder A R, AIME, New York (1981) 145.