Characterization of Materials Used for Rotavator Blades

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ABSTRACT

In rotavator, blades are generally made of medium carbon low alloy steels and during operation the blades are subjected to fatigue and abrasive wear. It results frequent replacement, which further added to equipment running cost as well as down time. The aim of this study was to identify suitable material and heat-treatment process to produce high quality wear resistant rotavator blade with affordable cost for the Indian farmers. For this the leading manufacturers/ dealers/ suppliers of rotavator blades were visited and interviewed, and samples were collected from twelve leading manufacturers/dealers of five states (namely Madhya Pradesh, Punjab, Haryana, Gujarat and Tamil Nadu) of India. Out of these twelve different blades six were selected for their chemical composition, mechanical & micro-structural studied. The study revealed that there was wide variation in chemical composition and mechanical as well as micro-structural properties of these rotavator blades. It was also found in the study that rotavator blades collected from the dealers of importers contained boron in trace level or some alloying elements.

Key words: Rotavator, Blades, Tillage, Rotary tiller, Seed bed preparation

INTRODUCTION

Based on survey of manufacturers of fast wearing components of agricultural implements, it was revealed that majority of manufacturers were using medium carbon steel (55%) followed by high carbon steel (27%), mild steel (12%) and high carbon tool steel (6%) (Singh and Saxena, 2008). Abrasive wear is a serious problem in fast wearing components of agricultural implements. The wear reduces the efficiency of farmers and costing huge loss of money. Long lasting agricultural implements can provide many advantages to the farmers like greater productivity, seeding in optimum conditions leading to more yields due to less changeover time, uniform ploughing, less fuel consumption etc (Ferguson et al., 1998). The combinations of hardness and wear resistance properties are the primary requirement of agricultural implements for reduction in wear rate and long lasting (Bhakat et al., 2007).

The tillage tools are generally subjected to abrasive wear, impact socks, and high tensile and bending loads in dry hard grounds. High carbon steels are found to be very useful for this application (Bliesener, 1953). Various heat-treatment processes and surface modification techniques have been used to overcome the wear situation of agricultural implements. Heat-treatment is a simple, flexible and cost effective technique for improvement in mechanical properties and wear resistance of agricultural implements. Heat treatment provides desired properties such as hardness, strength, ductility and wear resistance (Gupta et al., 2004). An optimum level of hardness only leads to the best wear performance of the steels (Jha et al., 2003).

Several studies reveal that for same material the amount of wear decrease when its hardness exceeded to that of abrasive (Arya and Singh,1960, Richardson, 1968). Boron steel exhibited better sliding wear and abrasive wear resistance properties than the high carbon steel. Boron present in small quantity (in ppm level) gives a good combination of strength, hardness, ductility, toughness and fatigue life. Chromium has significant effect on fatigue life. Higher hardness and strength in boron and chromium steel is due to mixed martensite-bainitic microstructure (Bhakat et al., 2004). Trace boron can enhance the harden ability of steels (¡ng and He, 2002). Typical applications of boron steels could be agricultural machinery blades, sweeps, points, triangular shovels, chisels, knife sections, shears and other soil and plant engaging components requiring higher wear resistance and strength, track segments for forestry machines, snow plough wear plate, crushers and other process machinery and all types of machine parts requiring high strength and wear resistance (Bhakat et al., 2004 and Anonymous, 2005).

MATERIALS AND METHODS

Twelve blades of rotavator were procured from different dealers / manufacturers in India. Out of these, six different blades were selected for testing their chemical composition and mechanical properties. On the basis of study four medium carbon low alloy steels two with boron and other two without boron were selected. Their chemical composition is given in Table 2. Rotavator blades were made from these steels and were heat-treated differently (Quenching and tempering in all four steels and Austempering in case of boron contained steels) in order to achieve varying microstructures. Three stage wear test (ASTM-G-65, rotary bin and field) were carried out on the rotavator blades made of selected steels and the two-collected specimen.

RESULTS AND DISCUSSIONS

Chemical composition, mechanical properties and microstructure of rotavator blades collected from various sources

The chemical composition, mechanical properties and microstructure of the samples of rotavator blades collected from various sources are depicted in Table 1. The table revealed that some manufacturers are using boron steels (which are more common for making soil working components of agricultural implements in European countries) or low alloying high strength steels containing Chromium and Vanadium. These alloying elements played vital role in micro-structural properties, which leads to improvement in mechanical properties and wear resistance.

Table 1: Chemical composition, mechanical properties and microstructure of rotavator blades collected from various sources.

Brand	%Alloying elements C	Si	Mn	Cr	B	Equivalents	Mechanical Properties UTS, MPa	Hardness HRC	Elongation %	Microstructure
Brand-1	0.54	0.43	0.60	1.04	-	EN-48	1215	48	5.19	Tempered martensite with coarse lath
Brand-2	0.77	0.35	0.57	-	-	EN-42	1189	44	5.85	Tempered martensite with coarse lath
Brand-3	0.72	0.38	0.60	-	-	EN-42	1192	45	6.27	Tempered martensite with coarse lath
Brand-4	0.77	0.40	0.72	-	-	EN-4	1203	45	6.12	Tempered martensite with coarse lath
Brand-5	0.50	0.22	0.82	0.53	0.0019	50B50	1470	48	9.51	Tempered martensite with fine lath
Brand-6	0.30	0.10	0.76	1.10	0.0035	30MnCrB4	1455	47	10.62	Tempered martensite with fine lath

UTS denotes ultimate tensile strength

It is clearly depicted from the above table that there is wide variation in chemical composition of the steels used for making rotavator blades. The Carbon, which is most influencing alloying element of steel varying from 0.30% to 0.77%. Similarly, the variation in Silicon was also found significant, but the variation in manganese was less (from 0.57 to 0.76%). The Chromium and Boron like alloying elements, which provide good combination of mechanical as well as tri-biological properties were found in some brands only. The influence of these alloying elements on mechanical and tri-biological properties is visible from the table. The values of UTS and % elongation were found to be considerably higher (brand 5 & 6) in comparison to other brands. These improvements were found due to fine laths of tempered martensitic formed during quenching and tempering of steels. The presence of Boron and Chromium in these steels further accelerated this tendency during heat-treatment.

Chemical composition, mechanical properties and microstructure of rotavator blades made from selected steels

Based on the chemical composition, micro-structural and mechanical properties of collected rotavator blades, four steels were selected and heat-treated. Their chemical compositions, mechanical properties and microstructure are given in Table 2. The table showed that plain carbon steel (EN-45), low alloy high strength steel (SAE-6150) steel and two boron containing steels (50B50 and 30MnCrB4) were used for the study. The table depicted that the formation of tempered martensitic structure with fine laths leads to higher mechanical properties like hardness (45-49 HRc), ultimate tensile strength (1195-1485 MPa), and percentage elongation (8-12%) in case of QT boron steels (50 B 50 and 30 MnCrB4 steels) similarly in high strength low alloy steel (SAE-6150steel). There is wide variation in chemical composition of the steels used for making rotavator blades. The Carbon, which is most influencing alloying element of steel varyies from 0.3 to 0.53%. Similarly, the variation in other alloying elements is also found significant. The table also revealed that boron steels and low alloying high strength steels containing Chromium and Vanadium were also taken in consideration for the study. These alloying elements played vital role in micro-structural properties, which leads to improvement in mechanical properties and wear resistance.

Abrasive wear of rotavator blades

The rotavator blades made from selected steels after heat-treatment were compared with two brands of rotavator blades at three different stages i.e. ASTM G-65, rotary soil bin and in field. The wear rate of EN-45 +QT is highest because of presence of low alloying elements in this steel and wear rate of 50B50 +QT steel is lowest one among all the tested steels as the boron improved hardenability and fine micro-structure in the steel during quenching and tempering. Boron leads to formation of boride that causes finer microstructure and results in considerably higher hardness when it quenched and tempered. SAE- 6150 steel does not contain boron, but it contains higher Cr and Vanadium. Vanadium is very strong carbide forming element and the vanadium carbides remains in the steel in very fine form and distributed uniformly, which makes the steel strong as well as tough, these factors lead to improvement in wear resistance, which makes this steel ranked second during all three stages of wear tests. The wear rate of 30MnCrB4 +Aus and 50B50 + Aus steels was comparable and lower than the wear rate of same steels under gone QT heat-treatment. The coarse laths in tempered martensitic structure and in bainitic structures leads to more wear rate because of less interfaces between the laths and lower hardness.

The wear rate could be reduced significantly through quenching and tempering treatment through generation of tempered martensitic structure with fine laths. These structures exhibit excellent combination of strength and toughness to control the abrasive action by the sand particles. The harder phase controls the abrasive wear to a great extent as it controls the penetration and scratching ability of the hard abrasive on the specimen surface. The wear rate of rotavator blades during three stages were found in same order i.e. Local 1>EN45 (QT) >Local 2> 30MnCrB4(Au) > 50B50(Au)>30MnCrB4 (QT) >SAE-6150 (QT) >50B50 (QT).

CONCLUSIONS

The study revealed that there is a vide variation in chemical composition, mechanical and tribological

Table 2: Chemical composition, mechanical properties and microstructure of rotavator blades made from selected steels.

Steel + Treatment	%Alloying elements C	Si	Mn	Cr	B	V	Mechanical Properties UTS, MPa	Hardness, HRC	Elongation, %	Microstructure
EN-45 + QT	0.53	1.77	0.70	-	-	-	1195	45	10.62	Tempered martensite with coarse laths
30MnCrB4 + Aus	0.30	0.08	0.75	1.05	0.0003	-	1345	45	12	Bainite [70%] + Ferrite [30%] uniformally distributed
50B50 + Aus	0.50	0.21	0.78	0.55	0.0005	-	1385	47	9	Coarse bainite: fine ferrite phase distribution in banitic matrix with some pearlitic region.
30MnCrB4 + QT	0.30	0.08	0.75	1.05	0.0003	-	1441	48	10	Tampered martensite; Fine matrix, carbides and borides distributed uniformly in the matrix.
50B50 + QT	0.50	0.21	0.78	0.55	0.0005	-	1485	49	8	Tampered martensite; Fine matrix, carbides and borides distributed in the matrix
SAE-6150 +QT	0.5	0.22	0.70	1.0	-	0.1	1456	48	11	Tampered martensite; Fine matrix, carbides distributed uniformly in the matrix.

UTS denotes ultimate tensile strength

properties of material used for making rotavator blades. It is also depicted that only a few manufacturers are aware of suitable heat-treatment of these blades. The wear ranking order of the treatments were found to be same in ASTM trials, soil bin trials and field-testing. The improved wear resistance of the QT treatments could be attributed to mechanical and microstructure features. And 50B50 steel ranked top.

REFERENCES

Anonymous. 2005. Boron steel, ttp://www.pitt.edu/~rjw9/engineerngevent.html.

Arya, SV and Sing Devinderpal. 1960. Wear testing of plough share, paper presented in Agricultural Engineering Symposium at IIT Kharagpur.

Bhakat, A K, Mishra, A K and Mishra N S. 2007. Characterization of wear and metallurgical properties for development of agricultural grade steel suitable in specific soil condition. *Wear*, 263 (1-6), 228-233.

Bhakat A K, Mishra A K, Mishra N S, Jha S. 2004. Metallurgical life cycle assessment through prediction of wear for agricultural grade steel Wear, 257, 338-346.

Bliesener WC. 1953. Farm equipment steels–A tillage implements metallurgist's viewpoints. *Agricultural Engineering*, Oct., 697-699.

Ferguson S A, Fielke J M, Riley T W. 1998. Wear of Cultivator Shares in Abrasive South Australian Soil, J. agric. Eng. Res., 69, 99-105.

Gupta A K, Jesudas D M, Das P K, Basu K. 2004. Performance evaluation of different types of steel for Duckfoot sweep application, Biosystems Engineering 88 (1), 63-74.

Jha, A K, Prasad B K, Modi O P, Das S and Yegneswaran A H. 2003. Correlating microstructural features and mechanical properties with abrasion resistance of a high strength low alloy steel. *Wear*, 254 (1), 120-128.

Richardson R D C. 1968. The wear of metals by relatively soft abrasive. *Wear*, 11, 245-275.

Singh D and Saxena A C. 2008. Status of Metallurgical techniques practiced by agricultural machinery manufacturers for fast wearing components in India., Vol. 32(3), 17-20.

ing X M and He X L. 2002. Effect of Boron addition on structure and properties of low carbon bainitic steels, ISIJ Int., 42, S38-S46.