# EFFECT OF MATERIAL PROPERTIES ON WEAR AND TEAR OF ROTAVATOR BLADES

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Tractor-driven rotavators are used to loosen the soil before disseminating seeds or transplants. The rotavator blades operate under a variety of loads, including the cyclic loading effect of the soil parts at the cutting edge. Rotavator blades fail due to higher stress gradients imposed on them during operation and deformation caused during operation. Due to the cyclic loading condition, the blade's fatigue strength and life will be impaired.

This study was prompted by a complaint received by leading agricultural machinery dealer on premature failure of certain rotovator blades. The objective of the study was to examine the failed samples and to propose suitable material and heat treatment methods to fabricate such blades locally that last long.

Samples of blades that have failed during operation and those that are available in the market have been collected and analysed under laboratory conditions. Three different types from three origins have been analysed. The mechanical properties such as elongation, tensile strength, yield strength, toughness and hardness have been used to compare the mechanical properties of different samples. The samples are identified as sample 1 sample 2 and sample 3.

The comparison of material properties revealed that sample 2 had the highest hardness, yield strength and tensile strength. However, its toughness and elongation were the lowest among all three. During the survey among farmers, this blade had the most frequent breakages. When comparing blade 1 with the other two, it had the lowest hardness, comparatively higher tensile and yield strength and moderate toughness. According to the survey among farmers, this blade was more prone to rapid wear. In contrast to sample 1 and sample 2, sample 3 had the highest elongation with the highest toughness with moderate yield strength, tensile strength and hardness.

Having studied the material properties required, it was decided to test a medium carbon alloy steel available in the local market. The analysis revealed that the sample obtained by quenching in and further normalising had the highest durability.

Keywords: Rotavator blade, Wear, Plough, Heat treatment

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## INTRODUCTION

Tractor-driven rotavators are used to loosen the soil before disseminating seeds or transplants. The rotavator blades operate under a range of forces, including the cyclic loading effect of the soil parts at the cutting edge (Vijay 2017). Due to the cyclic loading condition, the blade's fatigue strength and life will be impaired. Rotavator blades fail due to higher stress gradients and deformation caused during operation (Kumar and Mohanraj (2017).

A rotavator's useful life is 2400 hours (8 years), with 300 hours of use per year. According to Asl and Singh (2009), the blade tip or edges experience tremendous stress from the soil's constant varying impact. Blade wear occurs as a result of these forces after a specific amount of use.

This study was prompted by a complaint received from a leading agricultural machinery dealer on certain premature failures of rotator blades. The objective of the study is to examine the failed samples and to propose suitable material and heat treatment methods to fabricate long-lasting local blades.

## METHODOLOGY

Samples of blades that have failed during operation and those are available in the market have been collected and analysed in laboratory conditions. Three different types from three origins have been analysed. The mechanical properties such as elongation, tensile strength, yield strength, toughness and hardness have been used to compare the mechanical properties of different samples.

## RESULTS AND DISCUSSION

The samples are identified as sample 1 sample 2 and sample 3. The mechanical properties such as elongation, tensile strength, yield strength, toughness and hardness, and microstructure were tested and results are given in Table 1

**Table 1: Comparison of material properties of blades available in the market.**

| **Sample no** | **01** | **02** | **03** |
|---|---|---|---|
| Elongation | 3.2 | 1.74 | 4.49 |
| Tensile Strength (MPa) | 1309 | 1838 | 1163 |
| Yield Strength | 623.38 | 891 | 765 |
| Toughness | 53 | 39 | 79 |
| Hardness (Hrc) | 29 | 106 | 63 |

The comparison of material propoerties given in table 1 reveals that the sample 2 had the highest hardness, yield strength and tensile strength. However, its toughness and elongation were the lowest among all three. During the survey among farmers, this blade had the most frequent breakages. When comparing blade 01 with the other two, it had the lowest hardness, comparatively higher tensile and yield strength and moderate toughness. According to the survey carried out among farmers, this blade was more prone to rapid wear. In contrast to sample 1 and sample 2, sample 3 had the highest elongation with the highest toughness with moderate yield strength, tensile strength and hardness.
Having studied the material properties required, the next challenge was to identify suitable material from among stocks available locally. Having studied the required properties, it was decided to test a medium carbon alloy steel available in the local market. The chemical composition of the material is given in Table 2.

**Table 2 – Composition of the proposed material**

| Element | Content (%) |
|---|---|
| Iron (Fe) | 97 |
| Manganese (Mn) | 0.78 |
| Chromium (Cr) | 0.7 |
| Carbon (C) | 0.56 |
| Phosphorous (P) | 0.035 |
| Silicon (Si) | 0.15 |
| Sulfur (S) | 0.056 |

The received material is identified as sample 04. The mechanical properties of the sample are given in Table 3. The material demonstrated a higher elongation of 12% and a higher hardness of 98 HRC. However, the yield stress was as low as 260 MPa. In order to increase the material parameters, a sample was heated to 700 $^{0}$C and then quenched in water at room temperature. The water-quenched sample had a higher hardness. However, the sample demonstrated poor strength and elongation as shown in Table 3 under sample no 05. This is evident from the microstructure observation shown in Figure 01. The needle-like structure shows the formation of Martensite which is hard.

**Table 3 – material properties observed at each heat treatment stage.**

| Sample No | 04 | 05 | 06 | 07 |
|---|---|---|---|---|
| Elongation | 12 | 0 | 0.04 | 6.22 |
| Tensile Strength (MPa) | 710 | 0 | 472 | 1183 |
| Yield Strength | 260 | 0 | 526 | 953 |
| Toughness | 23 | 0 | 2 | 117 |
| Hardness (HRC) | 98 | 109 | 95 | **70** |

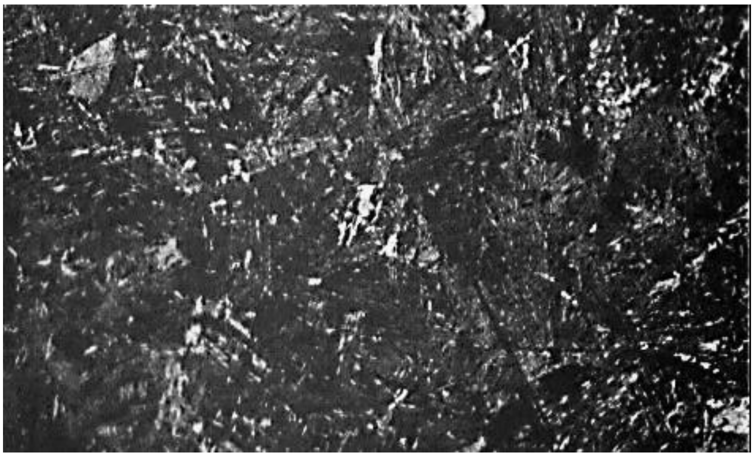

**Figure 1 – microstructure after water quenching.**

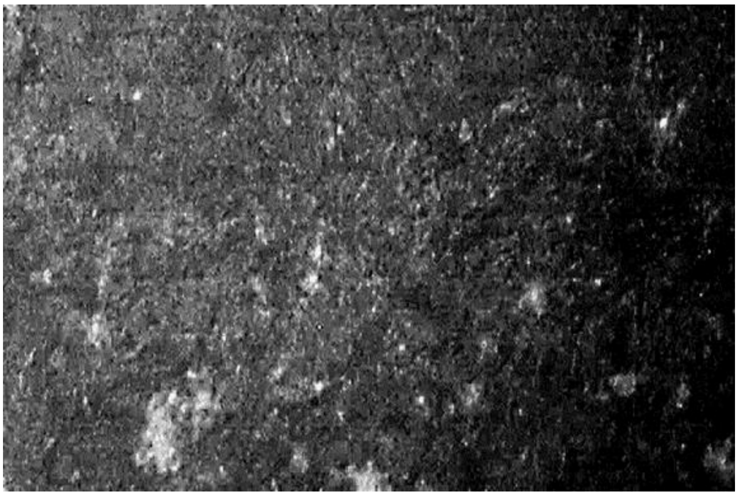

**Figure 2 - microstructure after quenching in oil.**

**Figure 3 - microstructure after normalizing**

As the second step, a sample was quenched in oil. Physical properties of the oil quenched sample are given in Table 3 under sample 6. The oil quenched sample demonstrated a higher yield strength of 526 MPa, ultimate tensile strength of 472 MPa but a low elongation of 0.04% and a lower toughness. The microstructure of the oil quenched sample is shown in Figure 2.
A sample which was heated to 700 $^0$C was normalized as the third step. Properties observed after normalizing are given in table 3 as sample number 7. Sample number 7 demonstrated a higher toughness, higher yield strength and higher tensile strength. The sample number 7 demonstrated a lower hardness compared to specimen no 4,5 and 6. However still it had a higher hardness compared to sample 3 which had the higher durability of all imported blades.


**Figure 4 – newly manufactured blades fixed to a rotavator.**

The newly manufactured 11 blades according to the specification of sample 7 were assembled to a rotavator at Angunakolapelessa.

## CONCLUSIONS/RECOMMENDATIONS

A comparison of sample 3 and sample 7 is given in Table 4.

**Table 4 - A comparison of the sample 3 and sample 7**

| **Sample no** | 03 | 07 |
|---|---|---|
| Elongation | 4.49 | 6.22 |
| Tensile Strength (MPa) | 1163 | 1183 |
| Yield Strength | 765 | 953 |
| Toughness | 79 | 117 |
| Hardness (hrc) | 63 | **70** |

The comparison reveals that the sample 7 is comparable with the imported sample identified as sample 3 and exceeds the mechanical properties. Compared to 765 MPa yield stress, the sample 1 and sample 2 had higher strength of 623 MPa and 891 MPa respectively. However, the reason for sample 1 to wear off rapidly was due to low hardness whereas the sample 2 to break frequently is due to low toughness. As depicted in table 4, a good combination of strength, toughness and hardness would make a good plough blade.

The newly manufactured blades, identified as sample 7, were tested under real-world conditions. They have been in operation for 140 hours, and no damages were reported as of June 2023. The assembly of the new blades in a rotavator is shown in Figure 4.

## REFERENCES


1) Vijay E. (2017). Design and Fabrication of Manual Ploughing and Seeding Machine. *International Journal for Research in Applied Science and Engineering Technology*, V(IX), pp.61–64. doi:https://doi.org/10.22214/ijraset.2017.9013.
2) Kumar, D. and P. Mohanraj (2017). Design and Analysis of Rotavator Blades for Its Enhanced Performance in Tractors. *Social Science Research Network*.
3) Asl, J.H. and Singh, S. (2009). Optimization and evaluation of rotary tiller blades: Computer solution of mathematical relations. *Soil and Tillage Research*, 106(1), pp.1–7. doi:https://doi.org/10.1016/j.still.2009.09.011.