# FAILURE ANALYSIS AND PROPERTY IMPROVEMENT OF COCONUT HUSK CHIPPING BLADE

***Wijesinghe N.C[1]., Galhenage A. Sewvandi*[1], Adikari J.[2]***

*Department of Materials Science and Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka[1]*

*Botanicoir Lanka (Pvt.) Ltd, Dankotuwa, Sri Lanka [2]*

## ABSTRACT

The exportation of coconut-based products is one of the major foreign currency earnings in Sri Lanka. Among those products, grow bags made from coconut husk chips perform a main role. The quality of the grow bags is highly influenced by the chip quality.

Existing coconut husk chipping machines consist of two half circular blades which are encountered with unexpected production difficulties due to fractures in the blade material and low lifetime. This failure of the blade ultimately leads to enhanced production time and cost, enhanced machine downtime, reduced product quality by inefficient chipping and high wastage of input materials. However, despite this component failing frequently, industrialists have no idea about the reason for the failure or a method to avoid the failure. Therefore, the objective of this study is to identify the existing blade material, analyse the reason for the material failure and proposed a treatment to avoid the failure.

Accordingly, a detailed failure analysis was carried out using an arc spark spectrometer, optical microscope and micro hardness tester. The study found that Type 01 blade was manufactured by cold work D2 steel. The undesirable primary carbide network (coarse carbides) present in there reduces the toughness of the steel and leads to material cracking and distortions. Also, the retained austenite is present in the cold work steel at room temperature due to different cooling rates and thermal contractions between the surface and core. It produces comprehensive residual stresses that ultimately lead to a hardness gradient along the cross section of the blade. It favours the crack generation and mechanical failures of the blade due to high anisotropy. This anisotropic mechanical response along the cross-section is mainly due to material type and lack of control of thermal treatments. In order to avoid the failure, residual internal stresses and hardness gradient were eliminated by tempering at 350°C.

**Keywords**: Coconut husk chipping blade, D2 steel, hardness gradient, tempering

* *Corresponding Author: galhenag@uom.lk*

# FAILURE ANALYSIS AND PROPERTY IMPROVEMENT OF COCONUT HUSK CHIPPING BLADE

***Wijesinghe N.C[1]., Galhenage A. Sewvandi*[1], Adikari J.[2]***

*Department of Materials Science and Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka[1]*

*Botanicoir Lanka (Pvt.) Ltd, Dankotuwa, Sri Lanka [2]*

## INTRODUCTION

Coconut is one of the major export crops in Sri Lanka. However, farmers are used to leaving the coconut husk as waste matter after harvesting the coconut. Manufacturing of grow bags for the international market using coconut husk chips is a great approach to turning such waste matter into money.

Grow bags consist of 50% of coco peat and 50% of coconut husk chips. The existing machine is susceptible to cut 4000 husks per 8 hours. Production of coconut husk chips produces 7%-10% fine particles and its accepted particle size is 3-6 mm. At the end of the lifetime of the chipping blade, fine particles will be produced which are below the accepted particle size with increasing wastage.

As per the industrialists, the lifetime of the existing blade is 8 hours, and the blade should be replaced once in every 8 hours and this replacement will consume around 30 minutes of labour time which reduces work efficiency as well as productivity. Therefore, an industrialist has tried out 3 different blades with different materials to enhance the service life of the blade in order to minimize the time, labour and material wastage. Among these three blade types, they have recommended Type 01 blades that have a comparatively higher lifetime due to wear resistance and good product quality; but, it is more prone to fracture during the cutting process. So, the company hopes to carry out a failure analysis and conducts proper treatment to avoid the fracture as it has good performance compared to other blade types.

**Figure 01.** Fractured Type 01 blades during the chipping process

Therefore, this study has focused on identifying the existing blade material and failure analysis, suggests a solution to avoid failure and enhance the service life of the blade by improving wear resistance. Ultimately, improve work efficiency and productivity by reducing time, labour, material wastage and machine failure rate.

## METHODOLOGY

### Chemical composition analysis

Three different types of unused coconut husk chipping blades were collected from grow bags manufacturing company and the following information about the blades were provided by the company.

**Table 01**. Information gathered from the industry

| **Property** | **Type 01** | **Type 02** | **Type 03** |
|---|---|---|---|
| Manufactured country | UK | China | Sri Lanka |
| Hardness/ HRC | 60 and 52 | 60 | |

| | | | |
|---|---|---|---|
| Lifetime/ hrs | >8 | 8 | <8 |
| Availability of fractures | Yes | No | No |

The chemical composition and manufacturing process of the blades were unknown but they had significant difference in service time and product quality. So, to identify their materials, chemical compositions of each blade type was analysed by a spark emission spectrometer.

**Micro hardness indentation test**

Hardness measurements were carried out via micro indentation method on the surface of Type 01 and Type 02 blades along the following axis. 40 measurements were taken from each sample to analyse the homogeneity of hardness throughout the blade. Using a micro hardness tester, Vickers' hardness of cross section was measured.

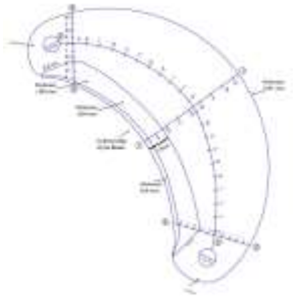

**Figure 02.** Schematic diagram of the blade

**Microstructure analysis**

The blade was cut into 1cm width samples perpendicular to the cutting edge. Blade pieces were ground using 240, 400, 600 and 1200 grinding papers to clean the surface. Ground samples were polished using a polishing motor with the presence of 1F µm Polycrystalline Diamond Serum. Polished samples were etched using 2% Nital Solution. The samples were cleaned and microstructures were observed from an optical microscope.

**Heat treatment by tempering**

The samples were tempered at 350ºC for 4 hours using an electric furnace to avoid a hardness gradient. The microstructures and hardness of the tempered samples were checked. Temperature was decided by the standard tempering graph of AISI D2 data sheet.

## RESULTS AND DISCUSSION

**Chemical composition analysis**

**Table 02.** Chemical composition and properties of blades obtained from the spark emission spectrometer

| Element % | Cr | Ni | Mn | Mo | V | C | S | Co | W |
|---|---|---|---|---|---|---|---|---|---|
| Type 01 (52 HRC) | 11.78 | 0.184 | 0.34 | 0.79 | 0.89 | 1.72 | 0.0092 | 0.0238 | 0.098 |
| Type 01 (60 HRC) | 12.09 | 0.182 | 0.35 | 0.74 | 0.81 | 1.52 | 0.0083 | 0.0292 | 0.102 |
| Type 02 | 11.97 | 0.35 | 0.46 | 0.41 | 0.165 | 1.39 | 0.008 | 0.0274 | 0.0212 |
| Type 03 | 0.38 | 0.011 | 0.75 | 0.01 | 0.0033 | 0.80 | 0.0057 | - | - |

Type 01 blade has a high Cr content which enhances the wear resistance and corrosion resistance. Mo element improves the wear resistance and reduces temper embrittlement. V presence in the metal improves the fatigue strength. High C content and the presence of W enhance the hardness and wear resistance which gives a higher lifetime to the blade compared to Type 02.

### Microstructure analysis

The following microstructures were obtained from the optical microscope to identify the Type 01 blade material in order to determine the cause of material failure and suggest a method to eliminate the failure.

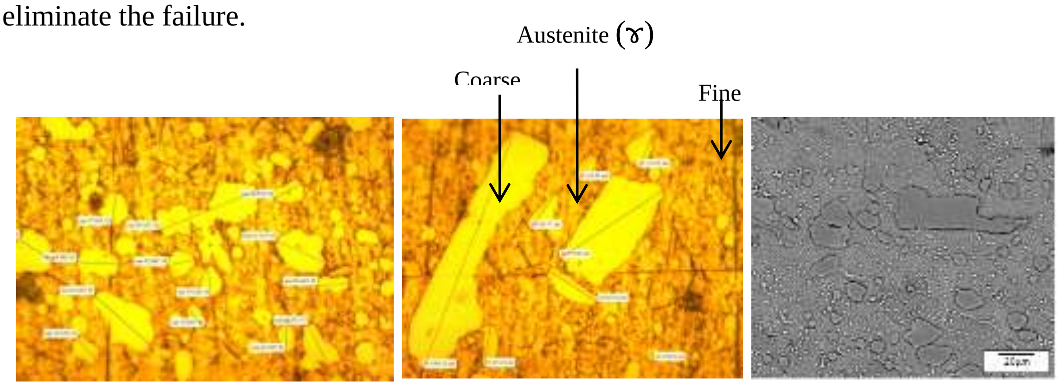


**Figure 03. (a), (b)** Microstructures of Type 01 blade obtained from optical microscope (×1000) **(c)** Microstructure of D2 in annealed condition [20µm] (Uzochukwu C.O., 2012)

The microstructures of Type 01 blade show coarse carbides, fine carbides and retain austenite occur during the soft annealed conditions which are similar to the D2 steel. These carbides can have a negative impact on D2 steel toughness and can make the material more prone to cracking and chipping. However, they also improve wear resistance and can help retain sharpness in cutting edges. Fine carbides can improve D2 steel toughness by acting as nucleation sites for microcracks which can help prevent larger cracks from forming and improve the wear resistance of the blade.

D2 is high carbon high chromium tool steel with vanadium and molybdenum. Type 01 chemical composition tallies with the standard AISI D2 composition. Based on the chemical analysis test results and microstructure analysis, type 01 blade material can be entitled to the D2 steel.

### Hardness profile

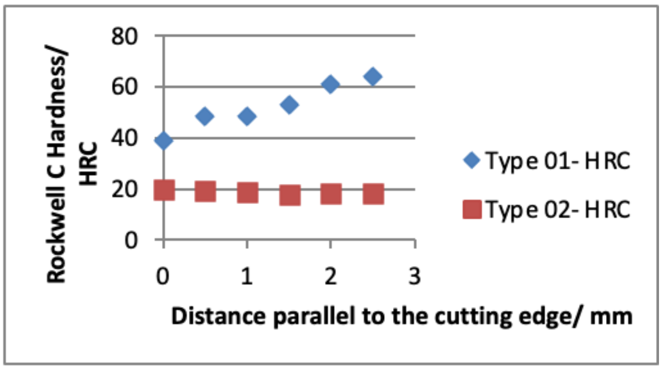


Figure 04. shows a significant hardness gradient along the cross section of the Type 01 and 02 blades. These high hardness differences in adjacent zones shown in Type 01 blade create low mechanical properties due to high anisotropy.

If the Type 01 blade is subjected to high stress or impact, a sudden change in hardness can create stress concentrations that can lead to cracking or fracturing.

**Figure 04.** Hardness profile of Type 01 and Type 02 blades along the cross section parallel to the cutting edge

**Tempering**

In order to avoid the failure, heat treatment was carried out as per the tempering graph of AISI D2 steel. Microstructures and hardness profiles of the treated samples were observed.

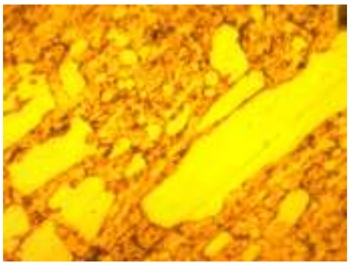

**Figure 05.** Microstructure of tempered type 01 blade

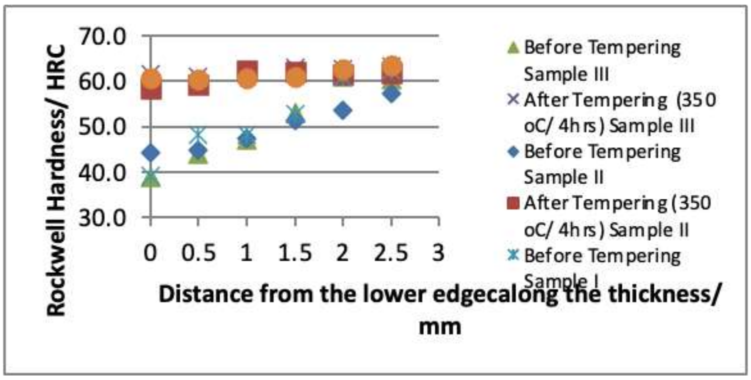


**Figure 06.** Hardness variation along the cross section after tempering

The hardness of the steel is affected by the retained austenite which depends on the material cooling rate of the manufacturing processes**.** Figures 05 and 06 show that retained austenite and hardness gradient have eliminated by the tempering.

**CONCLUSIONS**

Type 01 blade has manufactured by cold work D2 steel. So, the blade has good corrosion resistance, wear resistance and hardness which are required for coconut husk chipping application. However, cold work D2 steel contains an undesirable primary carbide network called coarse carbides which reduces the toughness of the steel and leads to material cracking and distortions. Also, D2 steel has retained austenite which causes hardness gradient and leads to mechanical failures. Therefore, Type 01 blade mainly fails due to the cross sectional hardness gradient of the blade due to retained austenite and undesirable primary carbide network in the steel.

**REFERENCES**

Beer, P., Rudnicki, J., Ciupinski, L., Djouadi, M., & Nouveau, C. (2003). Modification by composite coatings of knives made of low alloy steel for wood machining purposes. *Surface and Coatings Technology*, 434–439. Retrieved from www.sciencedirect.com

Makowiec, M. E., & Blanchet, T. A. (2017, March 15). Improved wear resistance of nanotube- and other carbon-filled PTFE composites. *Wear*, pp. 374-375. Retrieved from ScienceDirect: https://www.sciencedirect.com/science/article/abs/pii/S0043164816302721

Rodríguez, J., Duran, J., Aguilar, Y., Alcázar, G. P., & Zambrano, O. (2020). Failure analysis in sugar cane cutter base blades. *Engineering Failure Analysis*, *112*. Retrieved from www.elsevier.com/locate/engfailanal

Ahmad, R., Kamaruddin, S., Azid, I. A., & Almanar, I. P. (2012). Failure analysis of machinery component by considering external factors and multiple failure modes – A case study in the processing industry. *Engineering Failure Analysis*, *25*, 182–192. Retrieved from www.elsevier.com/locate/engfailanal

**ACKNOWLEDGMENTS**
*This study was carried out at the Department of Materials Science and Engineering, University of Moratuwa as a partial fulfillment of a Master's Degree. We hereby acknowledge the faculty for providing expertise knowledge and technical support to complete the project and also, acknowledge the staff of Botanicoir Lanka (Pvt) Ltd for the guidance and technical support to identify the research gap.*