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Cryogenic Treatment for Enhancing the Wear Resistance of Tool in Screw Briquetting Process

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Abstract

Cryogenic treatment which is done by super cooling materials around (-196ºC) with the aid of liquid nitrogen is one of the major heat treatment process used to improve wear resistance of materials. Partial cryogenic treatment is done from (-84^{0}C) to (-196^{0}C) for changing the properties to the required range. With temperature cooling time is also controlled for achieving the desired results. The application of cryogenic treatment methods on the tools used for making screw briquetting improves the wear resistance of the base material. There is a shortage of techniques to make good quality and long lasting tools for the process of making screw briquettes and due to this shortcoming the use of biomass as a fuel in commercial manner is seriously hindered. The highly abrasive nature of biomass wastes wears out the screw (tool used in screw type briquetting machine) at a very fast rate leading to production stoppages and cost overruns. This research examines the effect of cryogenic treatment on the screws used for briquetting biomass material. It was found that wear resistance has improved by 180% due to cryogenic treatment of the screws made of mild steel by comparison of its performance with other methods used is presented and its viability and shortcomings are discussed.

Key word: *Cryogenic Treatment; Biomass Briquette; Screw life; Wear Resistance; Surface treatment*

Graphical Abstract

Introduction

Biomass, the renewable, widely available and carbon neutral has the potential to provide significant portion of energy need in India. About 70% of population depends upon it for their primary energy needs which are about 32% of the total requirement. In India 150 million metric tons of bio waste is available as per the estimate and 17,000 MW of power can be generated out of it. The development of about a million hectare wasteland exclusively for biomass energy with high yielding grass varieties can generate roughly 1,000 MW. If the total potential of biomass is fully utilized, it can satisfy more than 10% of power consumption and will need about a trillion Indian Rupees as investment. Currently 5% of the existing potential is utilized even after several government resourcefulness. At the end of 2010 the installed capacity of India's biomass based power was about 1GW.

As agricultural residues have very low bulk density the major difficulties associated with them are handling, transportation and storage. If they are burnt directly in conventional grates the thermal efficiency is very low. Further they are of varying varieties and of different sizes and shapes, it is very difficult to sort, process and load before transporting. This problem can be

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reduced by biomass densification methods like briquetting [I. NeethiManickam et al 2006]. Biomass can be compressed by a ratio of 7:1 by the application of pressure between 400-800 MPa. Briquetting of biomass waste will improve its handling characteristics, improve volumetric calorific value, can be transported cheaper and can be made to desired uniform size and dimensions [K. Demirbas& A. Sahin-Demirbas 2009].In a screw extruder the biomass is compacted by passing through a die with the force of a screw press under elevated temperature and pressure. The biomass lignin turn out to be soft and it act as a binding material to transform into continuous mass at 300^{o}C temperature.The out coming continuous briquette should be cut at appropriate length of requirement.

The Screw type method generated briquettes are superior in density and strength than by other techniques [S.C. Bhattacharya et al] .Many studies are being done for improving the properties of steel by means of various surface treatments. The improvement of wear resistance quality of tool steels helps in improving productivity (K.K.Ray and D.Das 2017).

To reduce the level of wear affecting components Zurecki and others had coated with carbon steel and applying nitrogen by sparying (Z. Zurecki, D. Garg& D. Bowe, 1996). Thin films of ZrN coated in different thicknesses on 316 stainless steel and the corrosion resistance and wear resistance could be varied by changing the thickness of the films (J Menghani et al. 2013).

Das and Ray studied enhancement of wear resistance of steel tool by deep cryogenic treatment (DCT) (D. Das & K.K. Ray, 2012). The investigators identified, DCT precipitates ultrafine carbides and almost removes the amount of austenite retained and due to these microstructural alterations the wear resistance of tool steels improves. Joseph vimal et al (2008) by their research works found out that DCT decreases wear by 75% in En31 steel. The experimental results are before tempering and after quenching for promising results.

The retained austenite becomes 20-60nm thin film in between the martensite structure and the interstitial carbon atoms are precipitated helping to reduce friction (S.Li& X. Wu, 2015). KorayKılıçay& Mustafa Ulutan has studied the effect on the tribological behavior of steel coated with TiC composite and undergone cryogenic treatment. The coefficient of friction of the surfaces of specimens made of 38MnVS6 got considerably reduced from 0.373 to 0.236 (KorayKılıçay& Mustafa Ulutan 2017). Das et al (2007) identified that the carbon particle distribution and tribological properties are improved, if DCT was carried out in quenched and tempered D2 steel

AISI H11 steel was treated cryogenically in vacuum and studied for tribological behavior and it was found that H11 steel when treated for 21 hours and at -184^{o}C gave optimum results and no austenite was retained (SanjeevKatoch et al 2016). When PM S390 MC high speed steel was treated cryogenically and studied though the wear resistance was improved there was no corresponding improvement in toughness (FranjoCajner 2009).

The screw which is used for briquetting is usually made of various types of steels and hardened by coating with various hard materials like tungsten carbide or by using processes like quenching. To increase the strength and wear properties of steel various hardening methods are used. The steel can be hardened directly if sufficient carbon content is present and otherwise carbon composition can be increased with the help of various diffusion treatment techniques.

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The hardening process of subjecting the material to very low temperatures -185^{o} C approximately with the aid of liquefied gases and fetching back in normal conditions is called Cryogenic treatment

It enhances the mechanical properties of steel . The strength and hardness improved due to the improvement in the quantum of martensite. Carbon particle existing in the steel in the form of fine carbides got fixed by this treatment and enhance the wear resistance properties. The wear resistance improvement was attained by reducing the coefficient of friction because of of fine carbides presence and its matrix distribution.

Experimental Details

Briquetting Screw

Figure 1 Techno sphere coated sample. The Techno sphere is developed by densely coated nickel core wire and Ni Cr B Si alloy on Tungsten Carbide by applying Oxy-Acetylene welding technique. The heat treatment was done to convert austenite to martensite to the maximum.

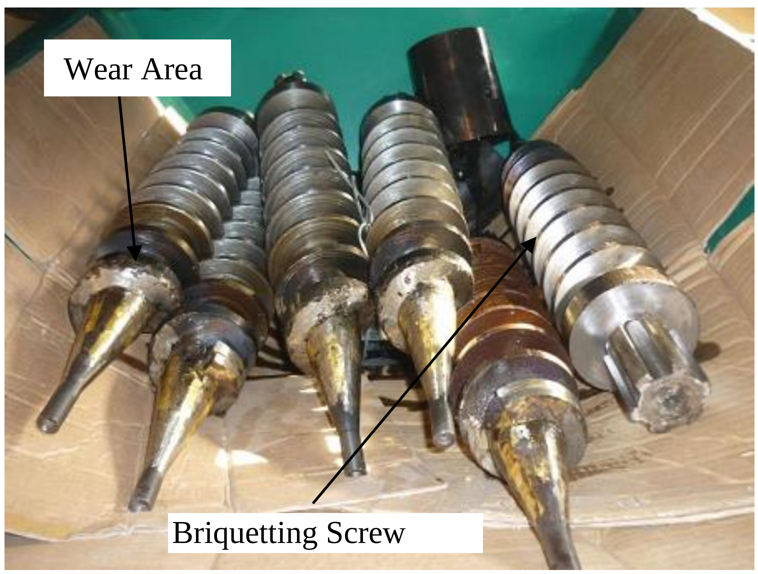

Fig.1. Briquetting screw

Through experimentation it was found that if the quench was lower than the traditional room temperature, A smaller amount austenite was retained if the quenching was done in the temperature lower than the room temperature.

Cryogenic treatment comprises freezing of parts to the temperature of liquid nitrogen (-196^{o}C) for a specific time called soaking time. The shallow cryogenic treatments of components are at up to -84^{o}C .The deep cryogenic treatment is temperature range -84^{o}C to -196^{o}C. The tempering process is carried out after cryogenic treatment. The literature study reveals that the deep cryogenic process increase the wear resistance and stability of materials. The transformations of martensite from austenite provide wear resistance because of structural density and wide surface area contact. It decreases the wear, stress, fatigue, friction and heat.

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Characterization analysis

SEM analysis was conducted and the figure 6.8 indicates the microstructure of specimen 4. It depicts the NiCr Matrix flow path and Spray Fuse Overlay with dense grain boundaries of path distance of minimum 2.1 mm and maximum of 2.3mm.Minimal dissolution of WC particles is visible with distinct crystal boundaries in microstructure figure. It resulted because of low LPG/Oxygen flame temperature in the welding procedure. By conducting the Rockwell Hardness test it was observed that , the bulk hardness 46 HRC is higher than that of specimen . It was because of fineness of grain size on the surface. 3000 HV0V was the observed reinforcement micro hardness for the specimen. The outcomes of the experiments indicate the reinforcement surface boundary hardness is comparatively greater when compared with the other specimens. It is due to spray fuse welded techno sphere.

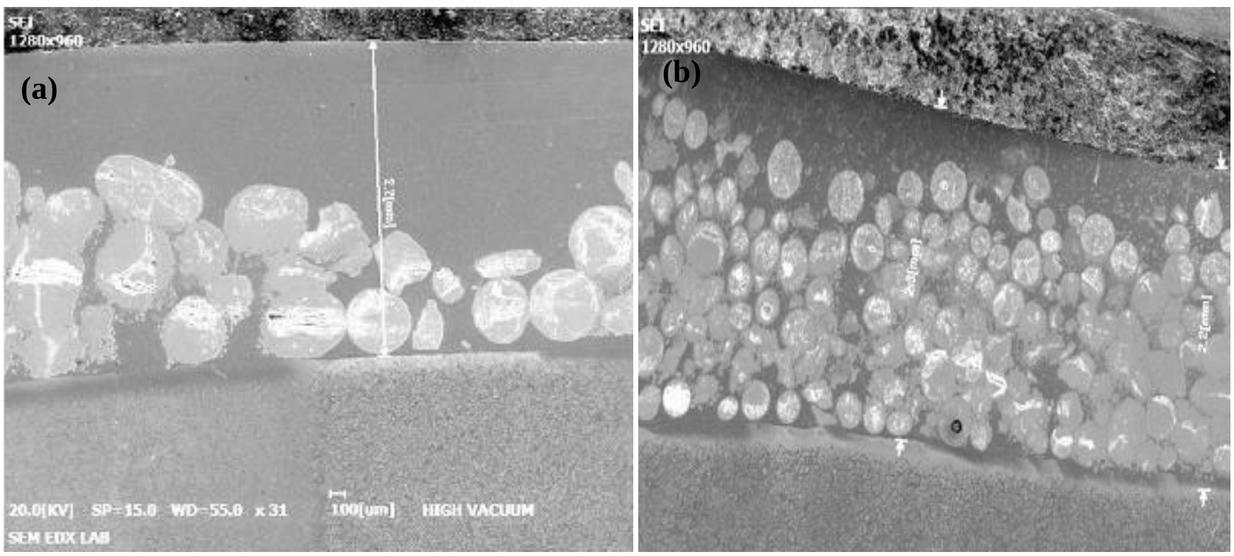

Fig.2. SEM

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Result and discussions

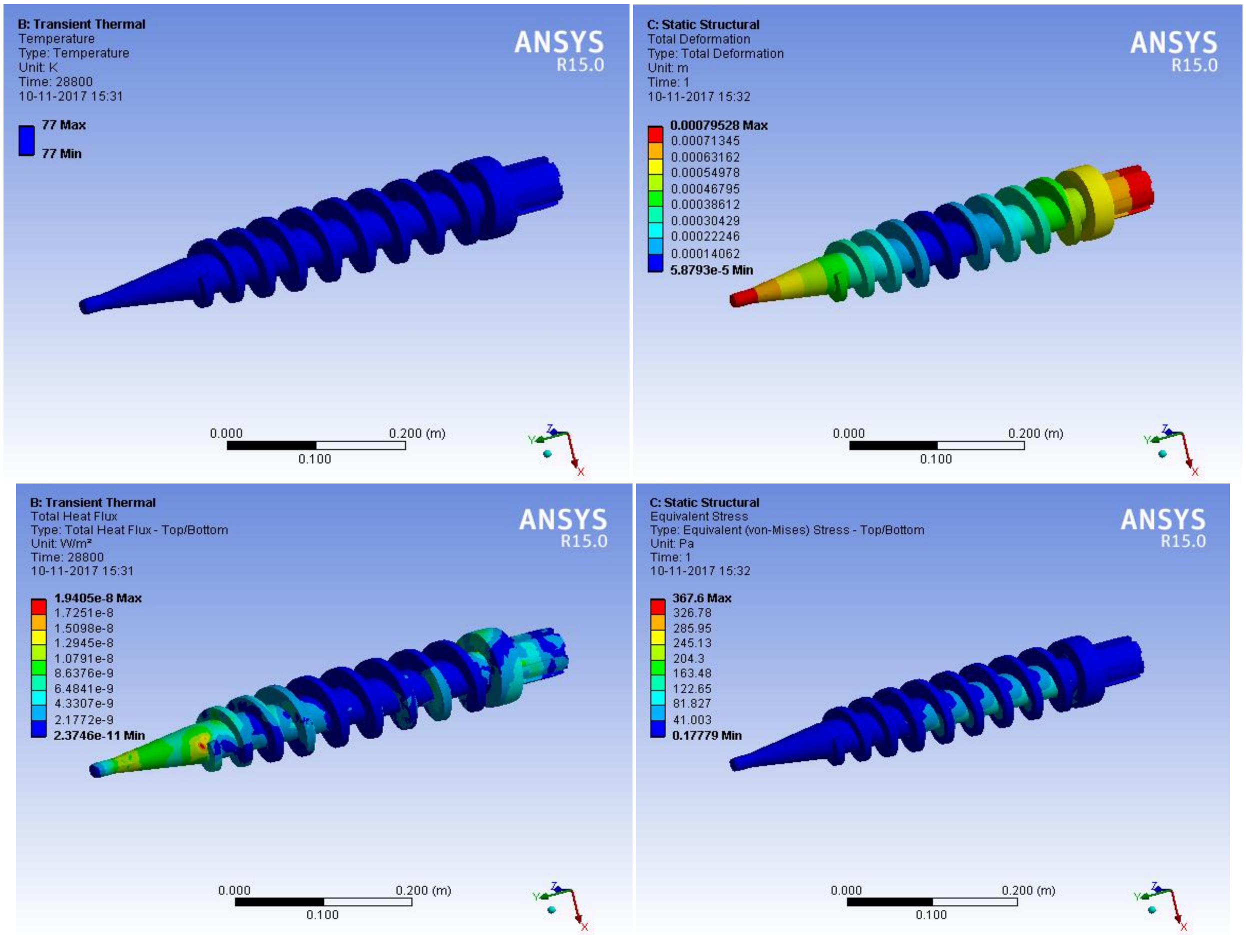

Fig.3. Analysis Report on Cryogenic treatment Briquetting screw

The cryogenic treated screw proved that the hardness of the screw compare than un treated screw. The wear resistance of the screw also increased with increase with increasing the hardness. From Figure 3, denotes the importance of the cryogenic treatment and improve the material properties.

From Figure 4, the heat flux and the time taken are highlighted the variations of heat flux minimum and maximum at the same time temperature distribution are identified. The peak values of the heat flux are 64.43 and 42.10, the temperature variation 260.24K and 260.26 K respectively 36 seconds.

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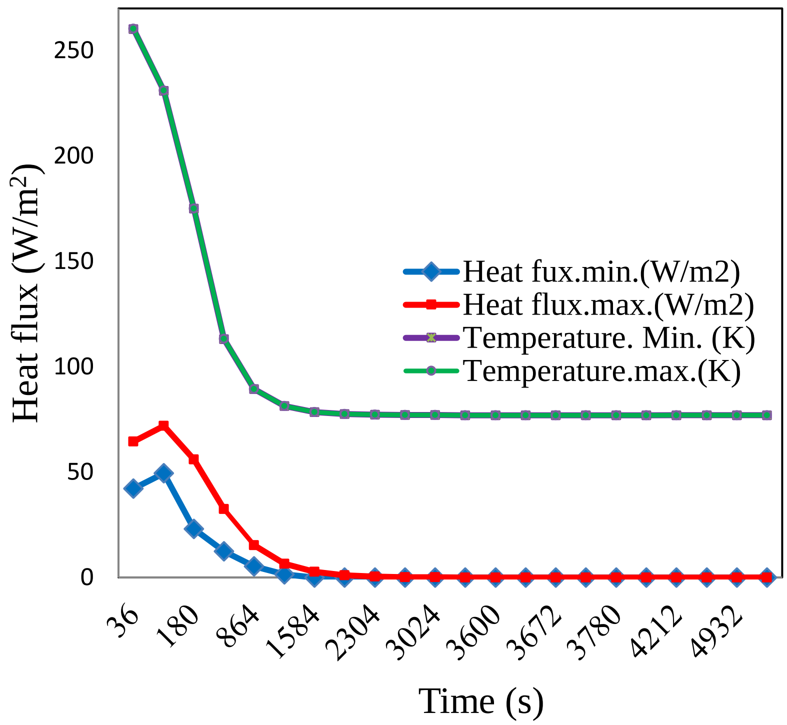

Fig.4. Analysis Report on Time with Heat Flux

The table 1 and figure 5 shows the comparison of screw life for various surface treatment process. Also compare with the other surface treatment process the cryogenic treatment material shows better life than others.

.Table 1: Comparison of screw life for different surface treatments

Sl.No	***Method of surface treatment***	***Screw life during testing***
1	Vautid 302 - Fe Matrix W2C powder - manual arc welding	10 to 12 hrs
2	Vautid 305 - NiCr matrix, W2Cpowder, Manual arc welding	17 to 20 hrs
3	Technodure - NiCr matrix, W2Cpowder, spray fuse welding	25 to 30 hrs
4	Technosphere - NiCr matrix, W2C spheroids, spray fuse welding	50 hrs
5	Cryogenic Treatment	140 hrs

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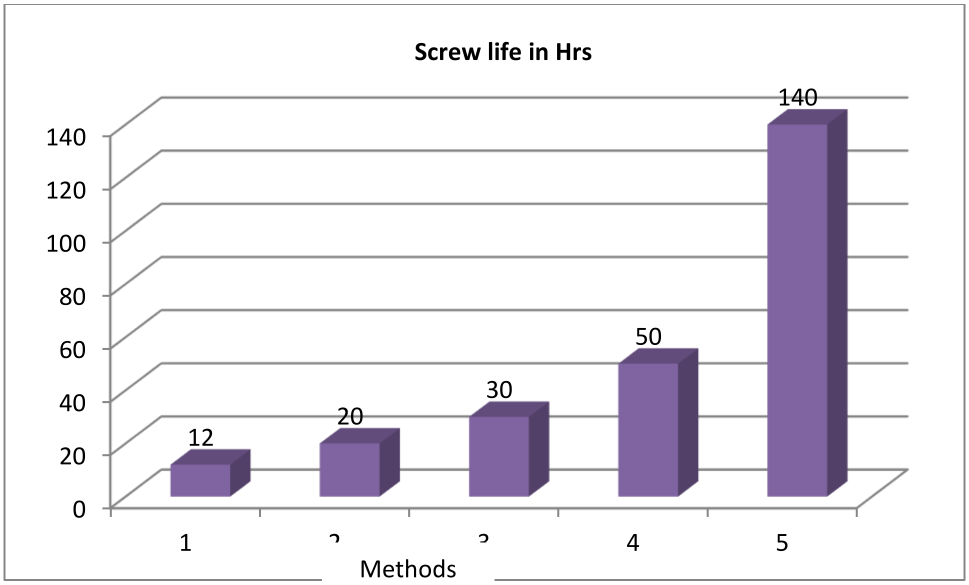

Fig 5: Comparison of screw life for different surface treatments

Conclusion

As the longevity increases, the production cost of tools per ton is reduced and achieved the profit. The present research work utilizing cryogenic treatment is applied in the screw used in briquette manufacturing system. The screw life was evaluated by implementing in a briquette manufacturing company.

The experimental results show the increased screw life. The life is improved, the cost of tools per ton of production is reduced to ¼ of the normal cost and this price reduction goes to profitability. In this present work screws four different coatings are considered for experiments. It was used in briquette manufacturing the screw life was observed. It is found that the cryogenic treatment improve the screw hardness and toughness due to the presents of alpha and beta iron. The life of the screw enhanced to 180% by cryogenic treatment after W2C treatment. The Wear resistance is also increased compared with other material coatings. From the analysis it is inferred that the improvement of hardness and the life of the screw in improve based on the phase changing phenomena.

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