Journal of Manufacturing Processes 26 (2017) 22–30

Contents lists available at ScienceDirect

Journal of Manufacturing Processes

journal homepage: www.elsevier.com/locate/manpro

Technical Paper

# On the processing of steel rod for agricultural conveyor systems: Materials characterisation and modelling

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ARTICLE INFO

*Article history:*
Received 26 August 2016
Received in revised form 10 January 2017
Accepted 16 January 2017

*Keywords:*
Finite element
Microstructure
Thermal
Ferrite
Grain boundary
Precipitate

ABSTRACT

A supply of medium carbon boron steel rod has been used industrially to produce the "rib-like" rod structures for mechanical conveyor systems, used across a number of non-safety critical industries, such as agricultural harvesting. The steel rod is resistive-heated and subsequently mechanically deformed such to produce a small region of flattened proportions, to allow for easier mechanical attachment to a belt system to attach all rods to the conveyor system. It has been noted industrially that after the flattening operations have taken place, a region at the shoulder of the flattened section is susceptible to cracking problems. The root cause of this cracking was desired to be understood, hence three likely causations for the cracking were explored, namely (i) mechanical stresses at the region, (ii) micro-segregation of the alloying elements at the location, and (iii) overheating. A 2D axi-symmetric finite element framework was developed to predict the stresses generated in the flattened section. This model showed that there were some areas of concern regarding the predicted effective stress and strain distributions, compared to the material flow stresses, thus potentially a mechanical reason for the cracking to occur. Microscopy methods were considered to understand the microstructure of the surrounding material and the nature of the cracks. However, these suggested that there was no likely element segregation to cause a significant variation in material property. Finally, temperatures generated by the resistive heating procedure were measured, and this does suggest that the material may have been overheated, thus producing coarser austenite grains whilst the material is held at elevated temperatures for a short time, and so producing inferior mechanical properties in this small region of heated material. The effects of overheating are impossible to eliminate without a complete re-melt of the steel. Thus, the research has demonstrated that a combination of overheating, and in-situ stress and strain distributions, could be the root cause of the cracking.



## 1. Introduction

The use of approximately 8–15 mm diameter steel round rod within predominantly non-safety critical mechanical conveyor systems to transport produce is relatively commonplace [1]. Thus, component non-conformance and "defect-tolerances" are admissible up to certain levels within the steel rods. Conveyor systems are widely used in a number of industries, including agricultural harvesting [1], whereby the produce can be transported from the lifted earth to a container attached to the harvesting vehicle, by means of a rigid conveyor system typically manufactured from alloyed steel rods, processed such that they can be joined using heavy-duty reinforced rubber or woven fabric to form a conveyor-system.

The medium carbon boron steel rods used in this work contained nominally 0.003 wt% boron. The addition of 0.0008–0.005 wt% boron to the steel is understood from the literature to significantly increase yield strength and UTS, improve the elongation of the steel, improve the impact toughness and enhance martensite formation [2]. Boron steels are also renowned for their high hardenability, thus are suitable for use in the production of rods which are to be used in both hot and cold forming operations and production of bolts or other rigid structures [3]. The boron acts as a grain refining addition to the alloyed steel, and upon quenching and/or tempering produces the finer grain structure which provides a more uniform material property across the finished part.

Medium carbon boron steel rod is commonly processed such that pieces of the rod of desired length are formed with flattened panel sections with a larger flat surface area than the remainder of

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http://dx.doi.org/10.1016/j.jmapro.2017.01.005
1526-6125/

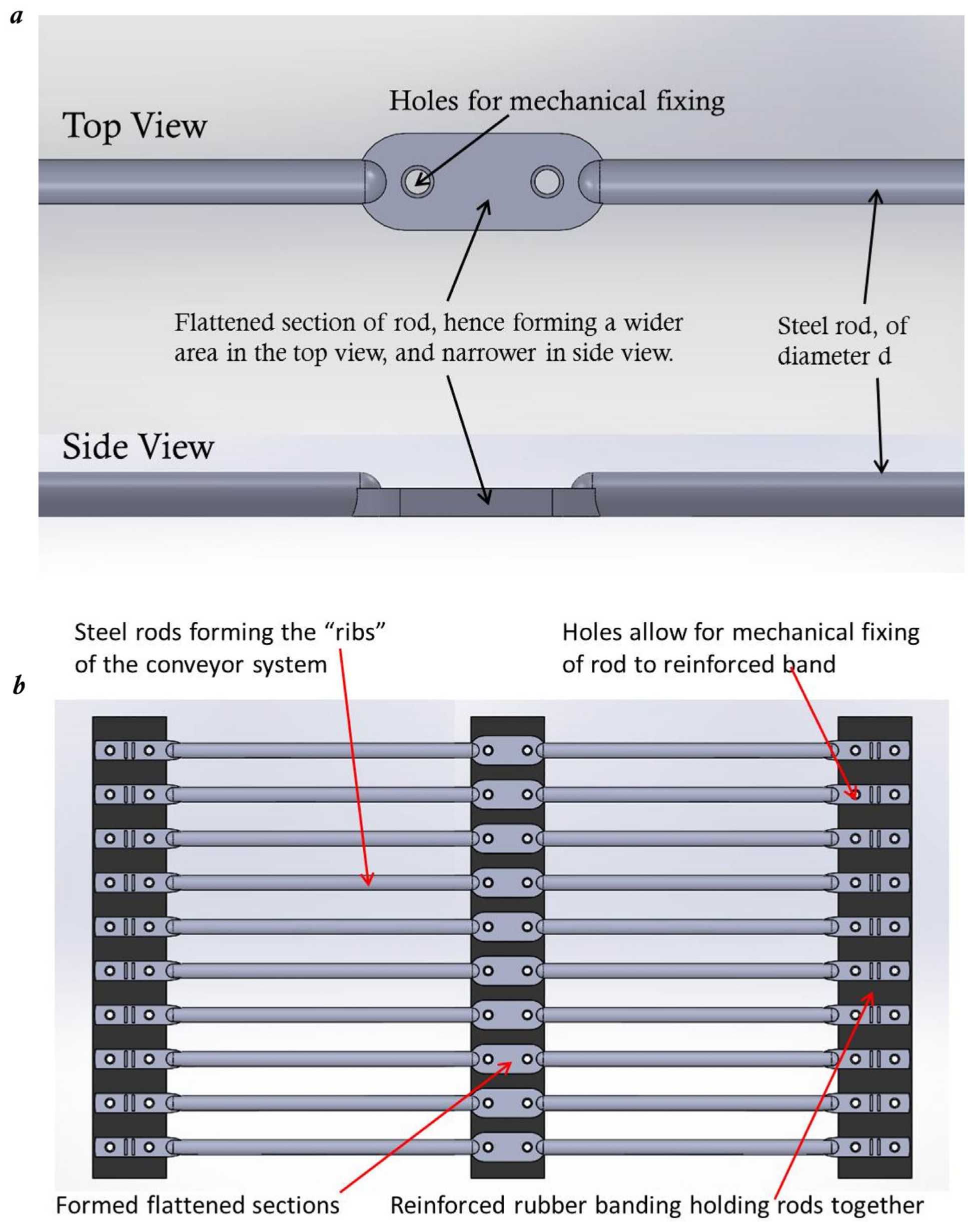


**Fig. 1.** (a) Sachematic of the forming of a flattened section for mechanical attachment purposes, (b)Schematic of the constructed conveyor system from processed steel rods with a flattened section.

the round rod (see Fig. 1a). This allows for holes to be introduced through the flattened sections, providing a mechanical fixture route to the conveyor's rubber belt system. Typically a flattened section would be formed at a central region, and at either end of the rod to allow for mechanical attachment of each rod at each location to the conveyor belt drive band (see Fig. 1b) with reinforced flattened sections about the centre which are subject to additional processes, as described below, prior to attachment to the central drive band.

The formation of the reinforced flattened section about the centre is performed in typically a number of operations, ideally linked together as a continuous processing route. Firstly, the section of rod to be flattened is heated using a suitable heating method. For speed, resistive heating is often employed. The rod, heated up to in excess of an estimated 1100 °C in this area, is then upset closed-die forged by a small amount. Clearly the flow stresses of the heated region are far lower than those of the cold remainder of the rod, hence all the distortion observed arises in the heated region of the rod, as it upsets into the closed die shape. This produces an intermediate rod product with a bulged section in all radial directions, at the relevant location on the rod where the flattened region is required. A subsequent operation is then performed to press this bulged region down to form something that is flattened, breaking the axi-symmetric condition of the rod which had been preserved until now, leaving the final flattened part which is less high than the rest of the rod, but considerably wider. Further processing operations see holes introduced through the flat area for mechanical attachment purposes (see Fig. 2).

During the processing operations, the steel is subjected to severe thermal and mechanical conditions. After the final flattening processing operation that the rod experiences, small cracks can occasionally be observed. These cracks typically occur in the shoulder area of the flattened section (see Fig. 3a). It therefore becomes of great interest to understand the driving mechanism for the cracking of the steel rod in these locations. It is considered that the cracking could have arisen due to a number of reasons: (a) Mechanically the rod has been subjected to stresses and strains from the form-