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Defects, causes and prevention controls in the continuous bronze/steel bimetal strip sintering process

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ABSTRACT

Plain bearings are among the most important components which determine the reliability and life of combustion engines. While bearing failures are well known, little consideration has been given to strip that is used to manufacture bearings, though defects in other sintered products are well understood. Bimetal strip defects can under certain circumstances lead to bearing failures in the field. Sintered bronze/steel bimetal strip production is a continuous process, in which the properties of the lining as well as the adhesion between the two dissimilar materials, bronze and steel, are developed during the sintering, compaction rolling, and resintering processes. This paper presents the results obtained by examining different defects in 1250 km of sintered bronze/steel bimetal strip, which was manufactured over three years in an industrial bearing manufacturing facility. The most frequently found defects are porosity, delamination, coarse bronze grains and coarse or non-homogenously distributed lead pools. Strip defects were examined and documented using micrographic analysis and photographs. Fault tree analysis (FTA) was performed to determine the root cause of the defects and prevention controls are discussed.

1. Introduction

Bronze is either cast on to the steel or applied by a powder-metallurgy technique to produce a bimetal strip. The advantage of the powder-metallurgy technique is that it confers a more isotropic structure and distribution of second phases independent of their lining thickness, though porosity exists. Fig. 1(a) shows CuPb10Sn10 that was sintered onto steel. Fig. 1(b) shows cast bronze CuSn4Bi with characteristic tree-like structure, called dendrite, in which crystal growth occurs faster along energetically favourable crystallographic directions resulting in consequences for lining material properties. For cast as well as sintered bronze/steel bimetal, the bond interface between the constituents is critical. When comparing the bond between sintered and cast bronze/steel bimetal, no significant difference can be observed as shown in Fig. 1. In both processes, diffusion between bronze and steel is extrinsic. Sintering is more economically viable compared to the casting process [1].

Both leaded and lead-free bronzes are considered in this study. Tightened environmental regulations have resulted in an increasing demand for lead-free materials with equivalent or superior properties to their lead-containing counterparts [2]. Many publications document damages and failures in plain bearings, while only a small number deal with defects and their occurrence in strip. Papers dealing with plain bearings focus on damage and failure classification and appearance [3,4], their possible root causes [5,6], corresponding corrective actions [7,8], effect of lubricants [9], diagnostics and examination tests [10], as well as the frequency of wear defect types in diesel engines based on field data [11]. Strip related papers describe sintering copper-based alloys to steel through various stages of manufacture [12], mechanical and wear properties as well as fatigue crack defects [1], and investigate the

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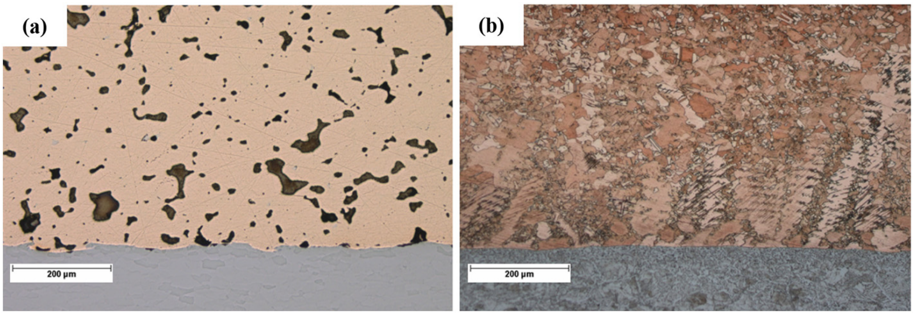

Fig. 1. Difference in microstructure for (a) sintered CuPb10Sn10 and (b) cast CuSn4Bi lining on steel backed bimetal.

influence of sintering and rolling reduction process parameters on the adhesion of bronze to steel [13]. However, to date papers have not focussed on strip defects originating from the manufacturing process, despite this being the process stage at which the detection and prevention has the greatest opportunity to reduce cost and business risk. This paper presents all defect types that took place in an industrial production site in a logical structure, analyses the critical process parameters and material characteristics to quality, and discusses control measures to prevent those defects from occurring.

2. The continuous bronze/steel bimetal sintering process

Fig. 2 shows a schematic of the process, which was used to manufacture the materials examined in this study. Steel strip is uncoiled, straightened and washed in a hot alkali solution to remove surface contamination and preservative oil. The bonding surface is linished using abrasive rotating belts, and then it is up-coiled and ready for powdering. Bronze powder is evenly spread over the steel surface using an adjustable powder die. The loose powder thickness is calculated based on the ratio between apparent density of the powder and theoretical density of the alloy, including an allowance for elongation of the strip during rolling. The bronze powder is sintered on to steel in a muffle type continuous sintering furnace at temperatures between 800 and 900 °C. Hydrogen (H_2) and Nitrogen (N_2) created by dissociating gaseous anhydrous Ammonia (NH_3) in the reaction $2NH_{3(g)} \rightarrow N_{2(g)} + 3H_{2(g)}$ [14] is used as reducing atmosphere inside the furnace during sintering. The hydrogen atmosphere prevents the bronze and steel from oxidising into the metallic state according to the reaction $CuO_{(s)} + H_{2(g)} \rightarrow Cu_{(s)} + H_2O_{(g)}$. This enables the de-oxidised particles which are physically in contact with each other and the steel surface to bond together due to mutual diffusion of their atoms and become a continuous network of bronze particles bonded to the steel backing. The density of the bronze lining after first sintering is higher than in the loose powder state, but still retains 20 to 30% porosity.

Sintering is either performed in a gas fuelled or electrical induction muffle type continuous sintering furnace. During first

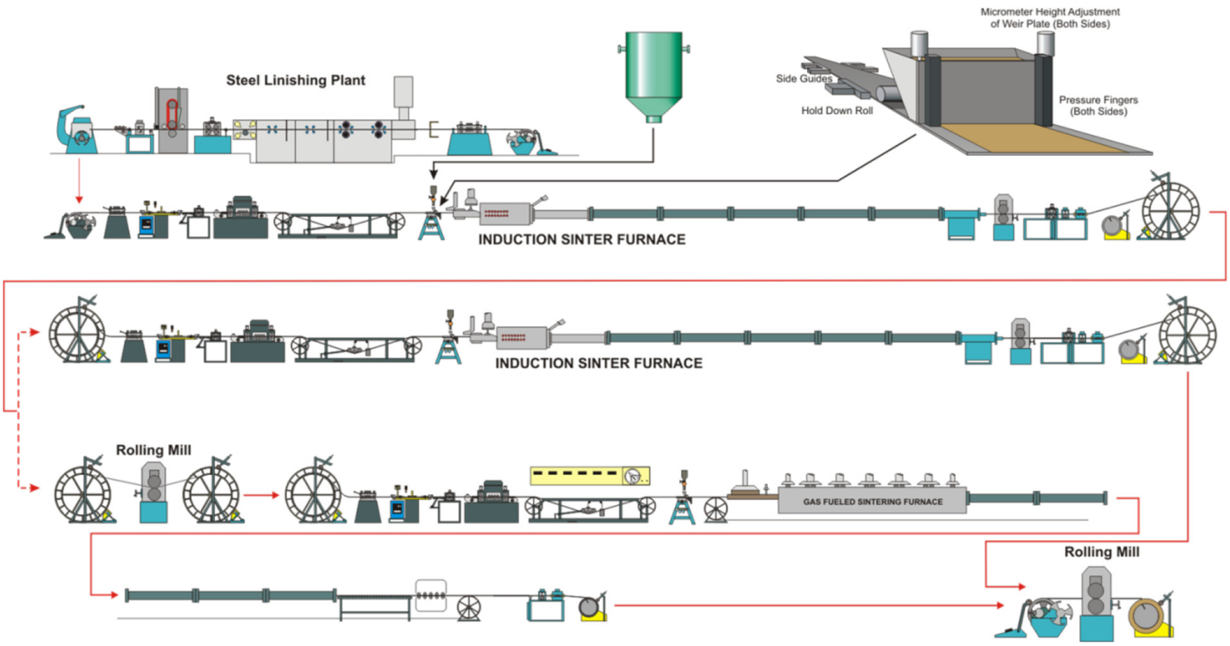

Fig. 2. Sintered bronze/steel bimetal continuous production process.