Microstructural and Micro-chemical Modifications of Borided Steels

ABSTRACT

The stringent demands made on the surface properties required in critical engineering components is causing an ever increasing level of research in getting the best of surface treatments of steel. So naturally several techniques have been developed for improving the surface characteristics of steel. The limitations on the attainable maximum values of hardness and other properties in conventional surface hardening techniques like case carburising, nitriding, flame hardening, induction hardening, hard plating, hardfacing, etc have paved the way for attracting techniques like boriding and its modifications. Plain boriding techniques also have some deficiencies, and the main objective of the present study is to address these deficiencies. Even though boriding can be used on different metallic systems, (including non ferrous alloys), the present investigation confines itself to the problems faced by steel components as a result of boriding.

The most important advantage of boriding is a phenomenally high level of hardness attainable, (1500 to 2000 HV), resulting in significant improvements in wear resistance, abrasion resistance, corrosion resistance, etc. However, the morphology of the iron borides forming on the surface of the steels causes a serious concern regarding the other mechanical properties of borided steels affected by their saw-tooth structure. The brittleness of the borided layer is a major cause of worry as it lowers the toughness of the structure. Also it can cause by virtue of stress raising nature of the sharp tips, micro crack initiation leading to failure of components in usage.

Although a large number of investigators have worked on boriding, a lot of scope still exists for further work to reduce the brittleness and improve the toughness and other properties of the borided surface layers. Embrittled surface layers are highly undesirable for very many critical applications. This research has been undertaken to change this morphology related deficiency of the borided steels.

Two major approaches were made for improving the microstructure and mechanical properties of the boride layers.

i. In the first approach, it was attempted to change the shape of the boride layers by microstructural modification, using intense heating to melt preferentially the surface layers alone and immediately allowing them to solidify. This is termed microstructural modification. Three different techniques have been proposed for this objective, tried experimentally, the optimal conditions for the same established and the characteristics of the resultant products studied and reported.

ii. In the second approach, it was attempted to change the micro-chemical nature of the surface layers by using multi-component boriding, wherein some additional alloying elements are introduced into the surface layers. Aluminium and chromium are the two elements that have successfully been introduced into the surface layers with this objective while boriding of steel. This introduction of these alloying elements not only helped in the formation of an improved interface between the case and the core, but also contributed to still higher hardness levels and significantly improved corrosion resistance as well. These techniques, individually referred to as boro-aluminising and boro-chromizing, have been experimentally tried, optimized in regard to conditions for best results, their products characterized and reported.

The materials used for this research are mild steel and medium carbon steel. The methods used for boriding were pack boriding (solid state) for micro-structural modification and electrolytic boriding (liquid state) for micro-chemical modification.

In microstructural modification, pack borided samples were modified by three different techniques, namely laser beam heating, induction heating and GTAW heating. All the three techniques were individually studied with regard to the optimal conditions and their products duly characterized.

In micro-chemical modification, electrolytic boriding was done in the molten salt mix containing boron source as well as the alloying element source, along with suitable additives to promote effective multicomponent case formations. The products were then characterized with regard to their mechanical as well as corrosion behaviour. They were also analysed by X - ray diffraction.

This thesis thus reports on the successful modification of the brittle boride layer by techniques established in these two different approaches, namely microstructural and micro-chemical. It is established that the microstructural modification that is achieved by the laser is also possible by the relatively more economical power sources like induction heating and GTAW heating. The micro-chemical modification techniques proposed and established show not only improved structure but also increased hardness coupled with enhanced corrosion resistance.