

SUPERPLASTIC BORONIZING ON DUPLEX STAINLESS
STEEL (DSS) USING COMPRESSION METHOD

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Abstract

The formation and growth of boride phases on duplex stainless steel (DSS) during superplastic boronizing (SPB) were studied in comparison with conventional boronizing (CB) from previous research. SPB is a surface hardening technique that combines boronizing with superplastic deformation. It utilizes the ultra high plasticity phenomenon in metal while carrying out boronizing in which boron atoms are diffused into the metal substrate to form hard boronized layer. The SPB process was conducted under compression mode at a strain rate of $2 \times 10^{-4} \text{ s}^{-1}$, at three different temperature conditions (1223 K, 1273 K, 1373 K) and strains (0.2 to 0.6). The microstructures and boronized layer growth were studied using optical and SEM microanalysis. A dense, smooth and uniform morphology of boronized layer was formed on all boronized specimens. Existence of boride phase on the substrate was confirmed by X-ray diffraction (XRD). Microhardness tests across the boronized layers were also performed. A boronized layer thickness in the range of 10.7 μm to 29.0 μm and surface hardness in the range of 302.7 Hv to 1687.7 Hv was obtained. The results indicated that boronized layer thickness and surface hardness of SPB is almost similar to CB. Under CB, boronizing at 1223 K for one hour produced boronized layer thickness of 19 μm and surface hardness of 1250 Hv. SPB at same temperature to a strain of 0.6 (50 minutes) produced a 17.3 μm thick boronized layer and surface hardness of 1252.5 Hv. The activation energy for SPB was also determined. Compared to the CB, the activation energy of SPB was reduced. The activation energy of SPB and CB was 111 kJ mol^{-1} and 192.1 kJ mol^{-1} respectively. In addition, SPB at 1223 K showed higher diffusion coefficient, K , $9.2 \times 10^{-14} \text{ m}^2 \text{ s}^{-1}$ compare to that of CB at same temperature, 5.44×10^{-14}

$\text{m}^2 \text{s}^{-1}$. Although the thickness of the boronized layer from SPB and CB were about the same, SPB reduced the energy required and provided a faster diffusion rate of boron into the substrate.

Keywords: *Superplastic, Boronizing, Compression method, Duplex stainless steel*

Abstrak

Pembentukan dan pertumbuhan fasa-fasa boride pada keluli tahan karat dupleks (DSS) semasa boronizing superplastik (SPB) dikaji berbanding dengan boronizing konvensional (CB) daripada kajian dahulu. SPB ialah teknik pengerasan permukaan yang menggabungkan boronizing dengan deformasi superplastik. Ia menggunakan fenomena keliutan tersangat tinggi dalam logam semasa melakukan boronizing di mana atom-atom boron meresap ke dalam substrat logam untuk membentuk lapisan berboron yang keras. Proses SPB cara mampatan dijalankan pada satu kadar terikan $2 \times 10^{-4} \text{ s}^{-1}$, tiga keadaan suhu (1223 K, 1273 K, 1373 K) dan terikan (0.2 hingga 0.6) yang berbeza. Mikrostruktur dan pertumbuhan lapisan berboron dikaji dengan menggunakan mikroanalisis optik dan SEM. Satu lapisan berboron yang bermorfologi tebal, rata dan seragam telah dibentuk pada semua spesimen. Kewujudan fasa boride pada substrat telah dipastikan dengan difraksi sinar-X (XRD). Mikrokekerasan juga diuji merentasi lapisan berboron. Satu lapisan berboron yang mempunyai ketebalan dalam lingkungan 10.7 μm hingga 29.0 μm dan kekerasan permukaan dalam julat 302.7 Hv hingga 1687.7 Hv telah diperolehi. Keputusan kajian ini menunjukkan ketebalan dan kekerasan permukaan lapisan berboron SPB adalah hampir serupa dengan yang CB. CB pada 1223 K selama sejam menghasilkan lapisan berboron yang ketebalannya 19 μm dan kekerasan permukaannya 1250 Hv. SPB pada suhu yang sama dengan terikan 0.6 (50 minit) menghasilkan lapisan berboron berketebalan 17.3 μm dan kekerasan permukaannya 1252.5 Hv. Tenaga pengaktifan SPB juga ditentukan. Tenaga pengaktifan SPB telah dikurangkan berbanding dengan CB. Tenaga pengaktifan SPB dan CB ialah 111 kJ mol^{-1} dan 192.1 kJ mol^{-1} masing-masing. Selain itu, SPB pada 1223

K menunjukkan pekali difusi lebih tinggi, K , $9.2 \times 10^{-14} \text{ m}^2 \text{ s}^{-1}$ bandingkan dengan CB pada suhu yang sama, $5.44 \times 10^{-14} \text{ m}^2 \text{ s}^{-1}$. Walaupun ketebalan lapisan beboron SPB dan CB adalah hampir sama, SPB telah mengurangkan tenaga yang diperlukan untuk boron meresap ke dalam substrat dengan kadar difusi yang lebih laju.

Kata-kata isyarat: *Superplastik, Boronizing, Cara mampatan, Keluli tahan karat dupleks*

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