Peningkatan Ketangguhan Impak Pada Sambungan Las Busur Inti Fluks (FCAW) Baja SM570-TMC Dengan Penambahan Nikel = Improving the Impact Toughness of FCA Welded SM570-TMC Steel Joint with Nickel Addition

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Abstrak

Baja SM570-TMC untuk aplikasi struktural membutuhkan kekuatan, ketangguhan, dan umur fatik tinggi. Namun pengelasan fusi pada baja ini dapat menyebabkan ketangguhan turun dan muncul tegangan sisa yang disinyalir sebagai salah satu penyebab kegagalan pada sambungan las. Beberapa hasil penelitian menunjukkan penambahan sedikit nikel dapat meningkatkan ketangguhan impak weld metal (WM) namun sifatnya kondisional sehingga masih perlu penelitian lebih lanjut. Disisi lain, untuk mengantisipasi kegagalan akibat tegangan sisa maka penting mendeteksi keberadaan tegangan sisa dan mengukur nilainya meskipun tidak mudah. Difraksi neutron adalah metode pengukuran tegangan sisa yang paling maju, namun teknik ini belum banyak dieksplorasi.

Penelitian ini bertujuan untuk mengevaluasi pengaruh nikel terhadap struktur mikro, ketangguhan impak dan tegangan sisa pada hasil pengelasan multi-pass baja SM570-TMC. Metode pengelasan busur inti fluks (FCAW) dan kawat las mengandung nikel 0,4%, 1%, dan 1,5% digunakan untuk fabrikasi sampel las LNi-04, LNi-10 dan LNi-15. Struktur mikro diobservasi menggunakan mikroskop optik, scanning electron microscope (SEM), energy dispersive x-ray spectroscopy (EDS), dan electron probe micro analyzer (EPMA). Ketangguhan impak diuji pada temperatur 25 °C, 0 °C, dan -20 °C. Tegangan sisa di sekitar sambungan las diukur menggunakan teknik difraksi neutron di kedalaman 3 mm dan 8 mm pada tiga arah sumbu: normal, transversal dan longitudinal.

Hasil pengamatan struktur mikro menunjukkan kehadiran acicular ferrite (AF) di LNi-10 lebih dominan dibandingkan LNi-04 dan LNi-15. AF ditemukan ternukleasi pada oksida kompleks yang tersusun atas Ti-Si-Al-Mn-Mg-O berukuran 1-2 m. Keberadaan AF berperan menghasilkan ketangguhan impak tinggi pada sampel LNi-10. Ketangguhan impak LNi-04 sedikit lebih rendah dari LNi-10, sedangkan ketangguhan impak LNi-15 paling rendah karena sedikitnya AF dan segregasi mikro. Hasil pengukuran tegangan sisa pada LNi-10 dan LNi-04 menunjukkan tegangan sisa di WM LNi-10 lebih tinggi daripada LNi-04. Penambahan nikel hingga 1% di WM meningkatkan kekuatan dan ketangguhan, namun tegangan sisa naik karena meningkatnya solid solution strengthening. Kedua sampel LNi-04 and LNi-10 menunjukkan tegangan sisa longitudinal lebih tinggi dibandingkan normal dan transversal. Tegangan sisa longitudinal maksimum LNi-10 ditemukan di WM, sementara pada LNi-04 terdeteksi di HAZ. Tegangan sisa longitudinal pada kedalaman 8 mm dari permukaan lebih rendah dibandingkan pada kedalaman 3 mm karena efek tempering dari pengelasan multi-pass. Dengan demikian, tegangan sisa kritis terdapat di dekat permukaan atas WM dan HAZ pada arah longitudinal.
......SM570-TMC steel for structural application needs excellent impact toughness, strength and fatigue life. However, fusion welding on this steel may affect to decrease impact toughness and initiate residual stresses

which contribute to the failure of welded joints. Based on reports from the earlier studies, the toughness of weld metal (WM) can be improved by adding small amount of nickel, but it’s conditionally so that further investigation still required. On the other hand, the residual stress and its value need to be detected in regard to anticipate the failure, however it’s not easy. Neutron diffraction is the advance method for residual stress measurement, but this technique is not much to be explored.

The purpose of this study is to evaluate effect of nickel on the microstructure, impact toughness and residual stresses of the multi-pass welding of SM570-TMC steel. The flux-cored arc welding (FCAW) and wires containing 0.4%, 1% and 1.5% Ni were employed to fabricate the welded samples of LNi-04, LNi-10, and LNi-15. Microstructure was observed using optical microscopy, scanning electron microscope (SEM), energy dispersive x-ray spectroscopy (EDS), and electron probe micro analyzer (EPMA). Impact toughness was measured at temperature of 25 °C, 0 °C, and -20 °C. The residual stresses around welded joint were measured using neutron diffraction technique at 3 mm and 8 mm depth and three directions: normal, transverse, and longitudinal.

Microstructure observation results showed the acicular ferrite (AF) was much found in LNi-10 compared to LNi-04 and LNi-15. AF was nucleated at complex oxydes which consist of Ti-Si-Al-Mn-Mg-O with diameter of 1-2 m. Impact toughness of LNi-10 is superior to the other as AF present. Impact toughness of LNi-04 is a bit lower than LNi-10, however impact toughness of LNi-15 is the lowest due to less AF and microsegregation present. Residual stress measurement result at LNi-04 and LNi-10 revealed residual stresss of WM at LNi-10 was higher than LNi-04. It seems that 1% of nickel addition in WM has increased strength and toughness, but the residual stress was also increased as effect of solid solution strengthening. Both LNi-04 and LNi-10 demonstrated the longitudinal residual stress was higher than normal and transverse. Maximum longitudinal residual stress of LNi-10 was found in WM, while maximum longitudinal residual stress of LNi-04 was detected in HAZ. Longitudinal residual stresses at 8 mm depth were lower than 3 mm depth due to tempering effect of multi-pass welding. It can be concluded that critical residual stresses were around WM and HAZ near top surface at longitudinal direction.