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Effect of Intermediate Intercritical Quenching on Low Temperature Toughness of Low-alloy Steel Forgings

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Typical heat treatment of structural steel forgings consists of quenching and tempering (QT). However, in case of heavy forgings (thickness above 120 mm), made of steels with carbon content less than 0.25% and low hardenability, the required strength can be achieved, but low temperature impact toughness could be not fully adequate. In this work, an intermediate intercritical quenching (IIQ) process, introduced between the conventional quenching and tempering treatments, was studied to improve the low-temperature toughness of heavy forgings made of low-alloy steels with C < 0.25%. After a design phase of the IIQ, validation of the proposed new heat treatment (Q+IIQ+T) was carried out by laboratory tests. The possible benefits of the IIQ treatment were evaluated comparing the mechanical properties and microstructures of forged coupons subjected to standard QT, double QT and Q+IIQ+T. Particular attention was paid to the toughness of the materials, which was measured by standard Charpy testing (V-notch transverse specimens) and fracture mechanics according to ASTM E1921 for determining the KJd (dynamic) parameter. The experiments showed that the introduction of the IIQ treatment, while maintaining the strength levels within the target values, leads to a considerable increase of low-temperature impact toughness, compared to the single QT and double QT, for the investigated steels (0.12-0.16%C, 0.7-1.35%Mn-1.5-2.0%Ni). A mixed microstructure was obtained after Q+IIQ+T, containing very fine ferrite and tempered martensite, which allows to achieve excellent low-temperature toughness. This behavior was attributed to microstructure refinement through reversed transformation during intercritical annealing. An industrial validation of IIQ was performed by manufacturing some prototype forgings that were investigated in terms of microstructures and mechanical properties. The industrial results confirmed that tensile strength of 490-510 MPa and yield strength of 340-380 MPa can be achieved with very high toughness levels, even in case of large thickness (up to 350 mm).

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