

Skip Firing in Medium Speed Dual Fuel Engines: Detailed Assessment and Engine Performance Optimization in Compliance with IMO Tier III

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Abstract

Medium speed dual fuel engines are in accordance with the strict IMO Tier III emission legislation, are economically competitive, do not require any exhaust gas aftertreatment, and allow fuel flexibility. Medium speed engines generally do not have throttling valves to reduce air pumping losses in high load range. Though this leads to a very lean fuel air mixture and an increased fraction of unburned fuel in low load. A valuable approach to reduce this methane slip and increase the efficiency is skip firing.

Skip firing was applied for a medium speed dual fuel engine based on a predictive 1D GT-Power simulation model that is validated against test bench data, raw emissions, and knock onset. Skip firing sequences were simulated, compared, and assessed according to the resulting load depending efficiency, methane slip, and NO emission. Based on the found effects of reduced NO emissions and increased efficiency, an optimization workflow was set up in the commercial optimization software Optimus. The selected evolutionary optimization algorithm varies the skip firing sequence as well as the relative air fuel ratio to optimize the load-specific engine efficiency under consideration of IMO Tier III and knock onset. The optimization is executed for discrete engine operation points in a load range to 64%.

The optimization predicts a significant increase of the brake efficiency and reduced methane slip at low and part load operation. Both depend on an increased turbocharger efficiency, reduced pumping work, richer combustion, and higher indicated mean effective pressures of the fired cylinders. The increased indicated mean effective pressure of the fired cylinders leads to an improved combustion (shifted from diesel to natural gas premix) and engine efficiency without exceeding the IMO Tier III NO_x emissions and knock limits.

Kurzfassung

Mittelschnelllaufende Dual-Fuel Motoren erfüllen die strenge maritime NO_x Emissionsrichtlinie IMO Tier III, sind wirtschaftlich wettbewerbsfähig, benötigen keine Abgasnachbehandlung und ermöglichen Kraftstoffflexibilität. Grundsätzlich besitzen Mittelschnellläufer keine Drosselklappe, um so Pumpverluste im oberen Lastbereich zu reduzieren. Das führt jedoch zu einem sehr mageren Gemisch und einem steigenden Anteil an unverbranntem Kraftstoff im Niederlastbereich. Ein geeigneter Ansatz um diesen Methanschlupf zu reduzieren und den Wirkungsgrad zu erhöhen stellt Skip Firing dar.

Skip Firing erfolgte für mittelschnelllaufende Dual Fuel Motoren, basierend auf einem prädiktiven 1D GT-Power Simulationsmodell, das mittels Prüfstandsdaten, den zugehörigen Rohemissionen sowie Betriebspunkten an der Klopfgrenze abgestimmt wurde. Skip Firing Sequenzen wurden simuliert, verglichen und gemäß dem resultierenden lastabhängigen Wirkungsgrad,