Booster concepts for increase of tractive effort

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Keywords

AC- and DC-linear drives, Booster concepts, Increase of tractive effort, 3D numerical calculation

Abstract

For modern locomotives with high mechanical power it is difficult to get the traction force onto the rail in case of bad weather conditions. With additional linear drives or with DC magnets mounted beneath the bogie of the locomotives it is possible to increase the tractive effort. Different types of these booster concepts are compared.

1   Introduction

With linear drives or special DC-magnets mounted beneath the bogie of a locomotive it is possible to increase the tractive effort. Three types of boosters are compared:

- A Linear Induction Machine (LIM) with the normal rail as secondary
- A Linear Induction Machine with an extra reaction cage in the track
- A DC–Actuator using the normal rail as secondary

The additional tractive effort due to linear drives is generated by two effects:

- Tangential linear additional thrust force ΔF_t of the linear drive,

- Increased wheel–rail adhesion force ΔF_z due to attractive force ΔF_n of the linear drive.

For example, the nominal vertical force per wheelset of German heavy duty loco class 152 is about 211 kN. With an adhesion coefficient $f_x = 0.36$ (dry rails) a maximum tractive effort (4 wheelsets) of $F_z = 4 \cdot 0.36 \cdot 211 \, \text{kN} \approx 300 \, \text{kN}$ is possible. The adhesion coefficient under wet weather conditions may decrease down to $f_x = 0.25$ or even lower. The tractive effort then is about $F_z = 4 \cdot 0.25 \cdot 211 \, \text{kN} = 211 \, \text{kN}$. If e.g. two boosters per bogie with an attractive force per booster of $\Delta F_n = 35 \, \text{kN}$ are mounted, an additional tractive effort of $\Delta F_z = 4 \cdot 0.25 \cdot 35 \, \text{kN} = 35 \, \text{kN}$, $35 \, \text{kN} \hat{=} 16.5\%$ of $211 \, \text{kN}$ is possible. If the linear drives also produce an additional thrust force of $\Delta F_t = 35 \, \text{kN}$, a total tractive effort of $F_z = \Delta F_z + \Delta F_t = 211 \, \text{kN} + 35 \, \text{kN} + 35 \, \text{kN} = 281 \, \text{kN}$ is achieved. Thereby nearly the full tractive effort is regained even when weather conditions are bad.

2   Linear Induction Machine with the normal rail as secondary

For the Linear Induction Machine mounted in the bogie it is necessary to stay within the limits which are demanded by regulations [1]. This leads to a LIM design similar to the eddy-current brake of ICE 3 [2], but with additional features such as speed–independent attractive force and thrust (Fig.1). A frequency inverter is needed to control the mode of operation of the Linear Induction Machine. In order to realise short winding overhangs and to avoid crossing of phases, a fractional slot winding with the number of slots per pole and phase $q = \frac{1}{2}$ was chosen, yielding three coils U, V, W per pole pair [3].