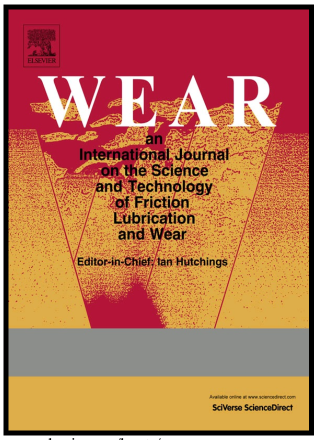

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Prediction of wheel and rail wear under different contact conditions using artificial neural networks

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Abstract:
Wheel and rail wear is a significant issue in railway systems. Accurate prediction of this wear can improve economy, ride comfort, prevention of derailment and planning of maintenance interventions. Poor prediction can result in failure and consequent delay and increased costs if it is not controlled in an effective way. However, prediction of wheel and rail wear is still a great challenge for railway engineers and operators. The aim of this paper is to predict wheel wear and rail wear using an artificial neural network. Nonlinear Autoregressive models with exogenous input neural network (NARXNN) have been developed for wheel and rail wear prediction.

Testing with a twin disc rig, together with measurement of wear using replica material and a profilometer have been carried out for wheel and rail wear under dry, wet and lubricated conditions and after sanding. Tests results from the twin disk rig have been used to train, validate, and test the neural network. Wheel and rail profiles plus load, speed, yaw angle, and first and second derivative of the wheel and rail profiles were used as an inputs to the neural network, while the output of neural network was the wheel wear and rail wear. Accuracy of wheel and rail wear prediction using the neural network was investigated and assessed in term of mean absolute percentage error (MAPE).

The results demonstrate that the neural network can be used efficiently to predict wheel and rail wear. The methods of collecting wear data using the replica material and the profilometer have also proved effective for wheel and rail wear measurements for training and validating the neural network. The laboratory tests have aimed to validate the wear predictions for realistic wheel and rail profiles and materials but they necessarily cover only a limited set of conditions. The next steps for this work will be to test the methods for rail and wheel data from field tests.

Keywords
wheel wear, rail wear, replica material, Alicona profilometer, wheel/rail wear prediction, neural network.

1. INTRODUCTION

Due to the geometry of the wheel and rail and the non-uniform distribution of normal and tangential forces between them the contact conditions at the wheel-rail interface are complex. Different levels of wear can occur at different points on the wheel and rail and surface [1] and an example showing wear at the tread and flange of a railway wheel is shown in Fig. 1 [2].

Fig. 1 Wheel wear [1]

Due to the vast length of railway track the cost of replacing worn rails is much greater than that of replacing any other damaged components [2]. Measurement of rail wear during inspection is normally made at three different positions as shown in Fig. 2: W1 is the vertical wear, W2 is the horizontal wear at a vertical distance h, and W3 is the wear measured at an angle α from the horizontal [3].

Fig. 2 Rail wear [3]

Wheel wear prediction is a very complicated process which is difficult to predict [4]. Rail maintenance and replacement represent some of the major costs of running a rail network. Rail lifetime is generally determined by two major factors; wear and rolling contact fatigue [5]. The development of wear mechanisms at the wheel and rail contact had been studied by various experimental and numerical methods.
Neural networks and other machine learning techniques have been used in earlier research to predict wheel and rail forces for railway operations [6] and to optimise the design of the railway suspension system [7]. They have also been widely used in railway and other industries for optimising tasks such as scheduling [8], [9] but they have not so far been applied to core engineering problems such as wheel or rail wear. Some relevant work is described below. Laboratory tests such as a twin disc test rig have previously been used to study the wheel and rail wear [10].

Singh et al., [11] used a back propagation neural network (BPNN) to predict drill wear. The inputs to the neural network in this work were thrust force, torque, feed-rate, drill diameter and spindle speed, while the output of the neural network was the flank wear. From the 49 datasets obtained in the experiment, 34 were selected at random for training the network, and the remaining 15 were used for testing the network. The simulation results show that the neural network is able effectively to predict the drill wear.