

Some new aspects of 150 years of history of wheel/rail contact mechanics – Extended summary

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1 INTRODUCTION

It is worth to look at the history of wheel/rail contact mechanics when looking at the present advances in contact mechanics. It is often forgotten, that there are several shoulders on which we stand. In wheel/rail contact mechanics F. W. Carter and J. J. Kalker are well known. However they are not the only ones. In 1855 Redtenbacher probably was the first one to look at wheel/rail contact mechanics. His motivation came from damage phenomena on wheel and rail surfaces. At this time not even a theory of normal contact was available. Only 27 years later Hertz published his theory on normal contact. - In 1883 Klingel was the first one to deal with the hunting phenomenon under purely kinematical aspects. However, this was not an analysis of critical speed. The first one who tried to do this was Boedecker in 1887. Then it took more nearly 40 years until Carter in 1916 published his investigations on the critical speed of a two-axled railway vehicle and ten years later on two-dimensional creep-force creep relations. No notice was taken of Boedecker's attempt, Carter's investigations were not accepted in his day. – Again 30 to 40 years later Johnson and Kalker started there more general investigations. Their investigations are the basis of most papers being published today.

2 REDTENBACHER, KLINGEL AND HERTZ

Redtenbacher's problem was a damage phenomenon on wheel and rail surfaces. No figures are found in his paper. However from his text it is clear, that these damage phenomena were head checks. Neither a theory of normal contact nor data for the yield limit of the wheel and rail steel were available for him. Redtenbacher was a classical mechanical engineer who was interested to solve this problem in spite of these deficiencies. And he found a solution [1].

Whereas Redtenbacher's problem was a problem of mechanical stresses the second problem was in the field of vehicle dynamics. Hunting phenomena of railway vehicles were observed not only for high speed traffic but already in the nineteenth century with comparatively low vehicle speed. Klingel described the hunting behavior of a single free wheel-set with conical profiles. His investigations were purely kinematic [2]. The main result is now called Klingel's formula: The wavelength of the sinusoidal hunting motion of a wheel only depends on the rolling radius, the track gauge and the conicity.

One year earlier, Hertz published his theory on normal contact of two half-spaces with second order surfaces [3]. During a presentation of his results in Berlin a railway engineer (we don't know his name) encouraged him to publish another paper focused on wheel/rail contact. Both papers appeared in 1882.

3 BOEDECKER, CARTER AND FROMM

Boedecker was the first who investigated in 1887 the critical speed of a railway vehicle with two wheel-sets using a simplified nonlinear creep-force/creep relation [4]. The same vehicle model has been used by Carter's investigations nearly 40 years later, however using a linear

creep-force/creep relation [5]. The principal results of both investigations were the same: A vehicle with two wheel-sets without primary suspension has a vanishing critical speed. Such a vehicle always performs hunting motions which are only limited by flange contact. It is interesting to look at the reactions of the auditorium, which are known in the case of Carter's presentation.

For his investigations of 1916 Carter used a heuristic, linear creep-force/creep relation. The creep coefficients (as we are calling them now) were unknown. Evidently Carter was impatient with this situation. Ten years later he was able to calculate the creep coefficients for a cylinder rolling on a plane assuming that both bodies were half-spaces [6]. In the same year Fromm in Berlin presented his dissertation where he renounced the half-space assumption [7]. For the problem of a cylinder rolling on a plane the results were identical.

4 FROM CARTER TO JOHNSON AND KALKER

Only thirty years later the main assumptions of the Carter-Fromm theory were loosened: the assumption of two-dimensional rolling contact and the assumption of completely elastic material behavior. Johnson's shake-down theory provides the possibility to include the yield limit into rolling contact analysis [8]. Vermeulen and Johnson [9] gave an approximate solution for three-dimensional rolling contact with longitudinal and lateral creep. The fully three-dimensional solution for rolling half-space contact was presented 1967 by Kalker in his dissertation [10]. These are the shoulders on which we stand.

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