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eMaintenance Solutions for Railway Maintenance Decisions

R. Kour, R. Karim, P. Tretten

Abstract— **The term eMaintenance emerged in the early 2000s and has become a popular topic in maintenance related literature because of ongoing technological improvements. This paper uses a recent approach, i.e. cloud-based technology, to provide an eMaintenance solution for online time data analysis to make effective and efficient railway maintenance decisions. Due to increased traffic, the Swedish railway sector needs to optimise maintenance, using predictive maintenance to a much higher degree so that unplanned breakdowns and downtime are drastically reduced. The paper shows how research within the railway sector is developing eMaintenance solutions using the cloud and web-based applications for improved condition monitoring, better maintenance and increased uptime. In the proposed solution, data are acquired from railway measurement stations and sent to the eMaintenance cloud, where they are filtered, fused, integrated and analysed to assist maintenance decisions. The paper provides a concept for a web-based eMaintenance solution to assist railway maintenance stakeholders make fact-based decisions and develop more efficient and economically sound maintenance policies.**

Index Terms— **Cloud, maintenance, eMaintenance, analysis, decision**

I. INTRODUCTION

For effective and efficient maintenance decisions, accurate and timely information must be available to all stakeholders involved in the maintenance process [1]. If the maintenance decision-making process is fully automated, cost effective maintenance decisions will result, facilitating, for example, diagnostic and prognostic processes. This paper is based on research within the railway sector on developing eMaintenance solutions using eMaintenance cloud and web-based applications for improved condition monitoring, improved maintenance and increased uptime. In its current context, the term cloud computing was first used in a 1997 lecture by Ramnath Chellappa to mean a “computing paradigm where the boundaries of computing will be determined by economic rationale rather than technical limits alone” [2]. In 1999, Salesforce.com became the first site to deliver applications and software over the Internet; in 2007 Salesforce.com expanded its efforts, with Force.com [3]. In 2002, Amazon added "Web Services" (AWS) and introduced the Elastic Compute cloud (EC2) as a commercial web service in 2006 [4]. Eucalyptus arrived next in 2008 with the first open source AWS API compatible platform for deploying private clouds, followed by OpenNebula, the first open source software for private and hybrid clouds. Google and Microsoft finally entered the playing field with Google Apps in 2008 and Windows Azure in 2009 respectively. Apple joined in with its development of the iCloud allowing users to synchronize photos, apps, music and documents across a string of devices [5]. Despite the widespread interest, however, cloud computing remains an evolving paradigm.

With cloud computing technology, data can be stored in the cloud, and these data can be visualised in a virtual machine to meet specific customer and application requirements [6]. A good eMaintenance solution needs to sense the context of the individual stakeholders to adapt the information to the stakeholder’s current situation [7]. The eMaintenance solution suggested here helps stakeholders to access data from the cloud anywhere in the world at any time according to their needs and requirements.

The aim of this work is to provide an eMaintenance solution using cloud computing for effective and efficient decision-making. Data are acquired from the railway wayside measurement stations located in northern Sweden and entered into the eMaintenance cloud. The wayside and onboard diagnostics equipment used by operators produce huge amounts of data. It becomes very difficult to pinpoint possible faults from these messy data; thus, tools must be developed to perform advanced data analysis and data mining. To this end, this paper uses the eMaintenance cloud for online data analysis and the visualisation of relevant information to assist railway operators in making maintenance related decisions.

II. EMAINTENANCE CLOUD

eMaintenance is defined at two levels of abstraction: first, “eMaintenance is maintenance managed and performed via computing”; second, “eMaintenance is a multidisciplinary domain based on maintenance and ICT ensuring that the eMaintenance services are aligned with the needs and business objectives of both customers and suppliers during the whole product lifecycle” [8]. This paper shows how web-based eMaintenance solution can use the Cloud to analyse and represent train track forces and wheel profile data to the end-users/ stakeholders. It draws on two data sources: forces data and wheel profile data. The data are integrated to ensure effective and efficient decision-making. Data from both sources are collected from the wayside measurement stations and sent to a field computer through

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wired connections; Radio Frequency Identification (RFID) technology has been used for data acquisition [9]. These collected data are sent to the eMaintenance cloud in the eMaintenance lab for data filtering, integration, analysis and, finally, visualisation to the relevant service personal.

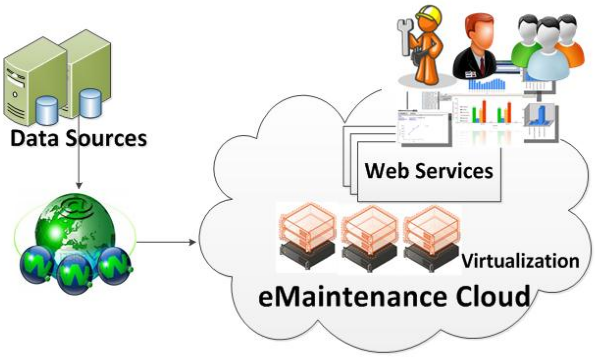

Fig. 1. eMaintenance Cloud with Web Services.

As noted above, the eMaintenance cloud can assist in online data analysis of railway traffic for improved maintenance. The eMaintenance cloud provides web services (Fig. 1) through which information can be exchanged electronically via desktop computers or mobile devices. Data are visualised through a process of virtualisation which provides a shared view and information services to different users. This concept to rail force data, including vertical forces, vertical loads, vertical transient, angle of attack etc., and to wheel profile data, such as flange height, flange thickness, flange slope etc., for a specific train wheel. Data from these different data sources are acquired, filtered, integrated and analysed so that cost effective maintenance decisions can be made.

III. Methodology

In the present work, extensive consultation with stakeholders has resulted in our analysis of track forces and wheel profile data. The research methodology ranges from initial data collection to data presentation in the form of web services. Data are collected from the measurement stations and sent to the eMaintenance lab, which provides cloud services to enable diagnostic and prognostic eMaintenance decisions. More specifically, the eMaintenance cloud provides web services to share online data so that the needs of various stakeholders can be met. The research methodology is shown in Fig. 2.

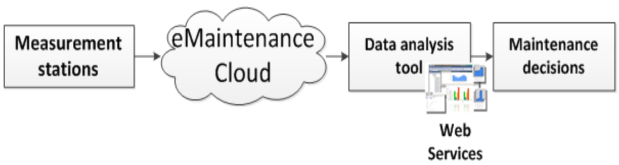

Fig. 2. Research Methodology.

A. *Data collection*

Data are collected from two railway wayside measurement stations outside Luleå, Sweden. The first data source is the automatic wheel profile measurement station. This station measures wheel profile data, such as flange thickness, flange height, rim thickness, flange slope, tread hollow, diameter etc. (fig. 3).

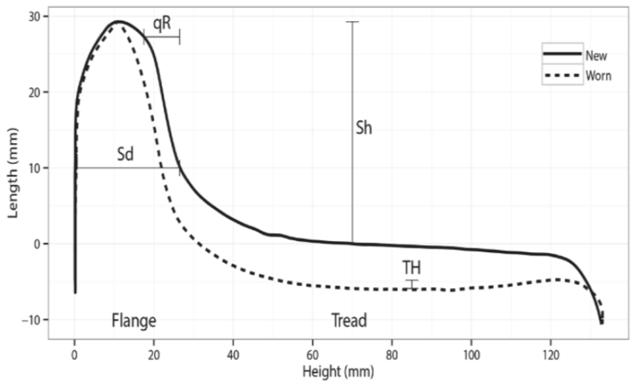

Fig. 3. Original and worn wheel profiles measured by the wheel profile measurement system. The wheel profile parameters are illustrated in the figure. Sh: flange height, Sd: flange thickness, qR: flange slope, and Th: tread hollowing "to be published" [10]

The second measurement station collects rail force data, including lateral and vertical forces, vertical load, vertical transient, angle of attack etc. An RFID Tag is implanted on each vehicle of a train; it receives a signal from the RFID reader and gives a return signal with its identification number. The RFID reader then reads the data and sends them to a nearby database server for storage [9]. These measurement stations are connected to the eMaintenance cloud via a global system for mobile communications; GPRS. The purpose of both wayside measurement stations is to continuously retrieve data for ongoing and future research projects, improve the maintenance of both rolling stock and infrastructure to diagnose the condition of the wheel and rail, and to optimise their maintenance [11].

B. *Data analysis*

The collected data are analysed to extract information and knowledge. The eMaintenance cloud then provides web services through which the information can be disseminated electronically. This work uses ASP.NET as the front-end and SQL Server 2012 as the back-end to develop the web application, i.e. an eMaintenance data analysis solution to present data to users.

C. *Data visualisation*

Simply stated, data visualisation supports maintenance decisions. Criteria for visualisation can be user specific to find specific deviations. In this case, the eMaintenance solution conducts online data analysis of the condition of each wheel. Wheels not within threshold values are presented in the app (software application) available to the relevant users. In the app, if any wheel is visualised as approaching or crossing its threshold limit, the railway operator can make the appropriate maintenance related decision. Further, for any specific train, the force data and wheel profile data can be graphically visualised as shown in Figs. 4-7.

IV. Results and Discussion

The eMaintenance solution is a graphical user interface which allows stakeholders to visualise data depending on their specific needs. Fig.4 shows a web-based eMaintenance solution; it provides the historical data for a number of trains passing by the wayside measurement station.

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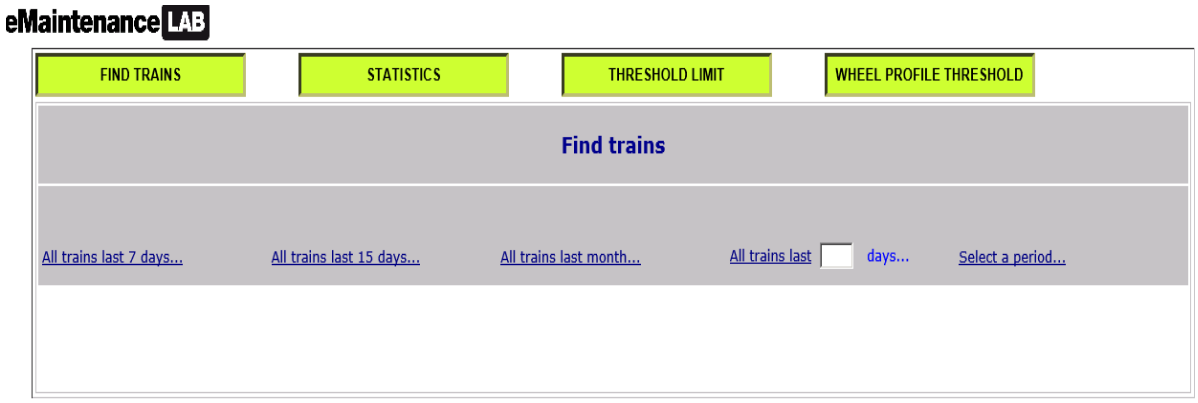

Fig. 4. Screen shot of web-based eMaintenance solution

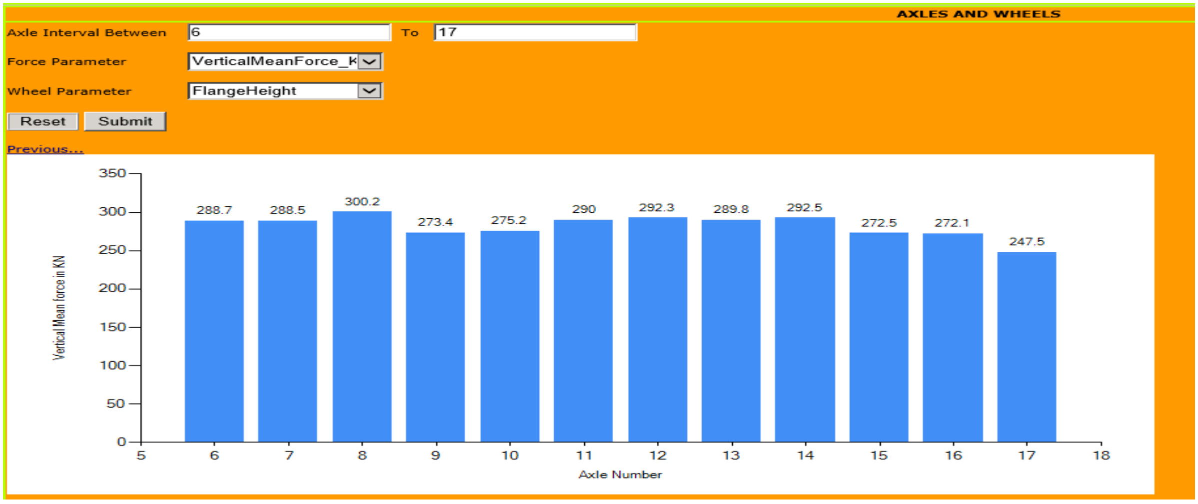

Fig. 5. Chart showing Forces data.

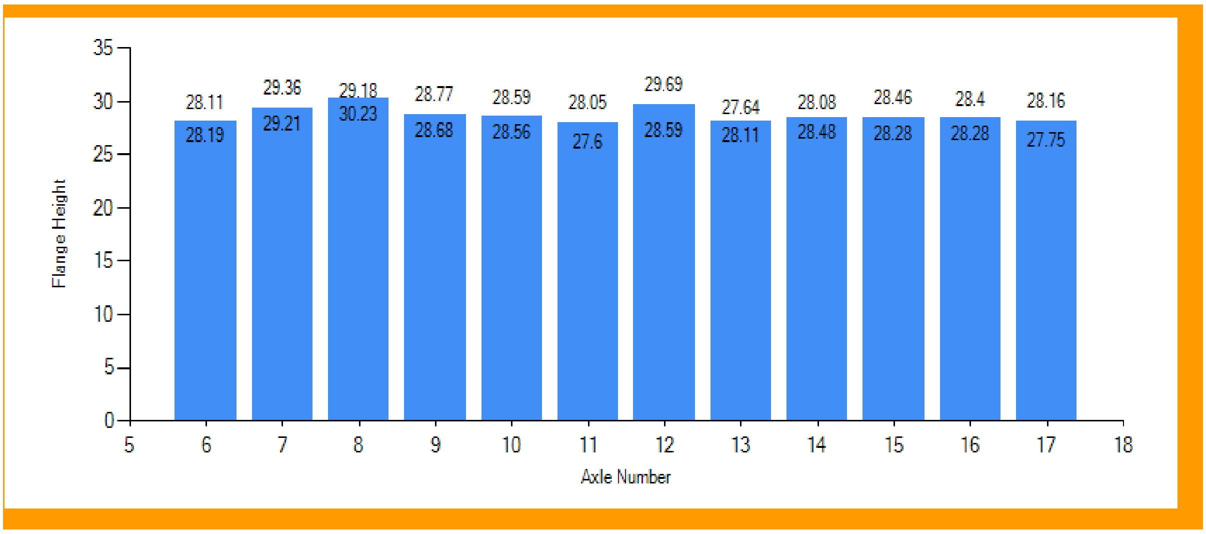

Fig. 6. Chart showing Wheel Profile data.

Depending on the specific period, data on trains can be visualised for end users in the form of either grids or graphs.

For any range of axles, for example, axles 6-17 on a specific train, the rail forces data (Fig. 5) and the wheel profile data (Fig. 6) for the left and right wheel can be presented to end users in a graph. In addition, different wheel profile parameters within the threshold limit can be displayed and the data analysed; i.e. how many wheels have crossed a certain threshold limit. Table I shows the maintenance limits set by the operator and safety limits determined by the infrastructure manager.

TABLE I
SAFETY AND MAINTENANCE LIMITS FOR WHEEL PARAMETERS
“to be published” [10]

	Maintenance Limit	Safety Limit
Flange Height	34 mm	36 mm
Flange Thickness	22.5 mm	22 mm
Flange Slope/Angle	7 mm	6.5 mm
Hollow Wear	1.5 mm	2 mm

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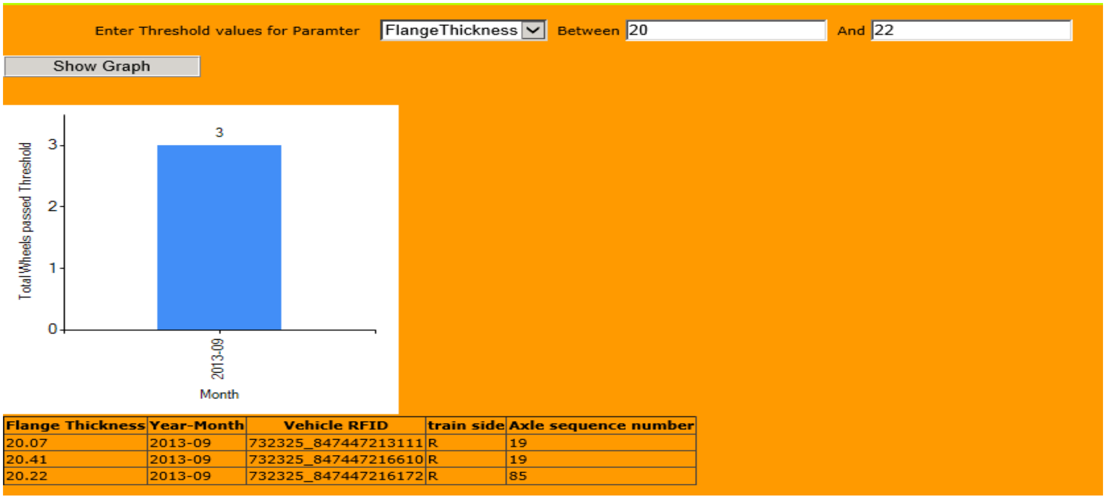
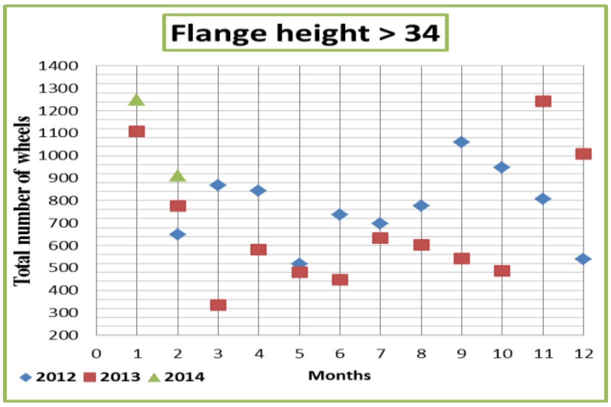


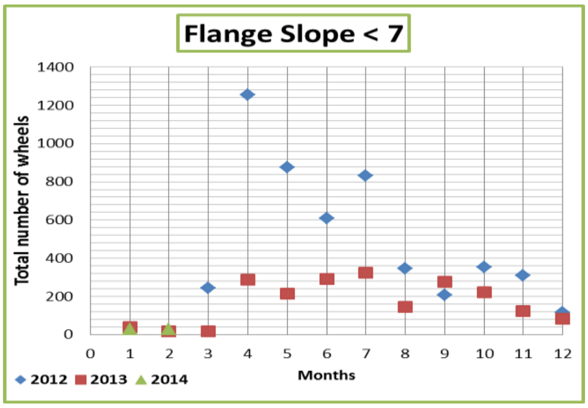
Flange Thickness	Year-Month	Vehicle RFID	train side	Axle sequence number
20.07	2013-09	732325_847447213111	R	19
20.41	2013-09	732325_847447216610	R	19
20.22	2013-09	732325_847447216172	R	85

Fig. 7. Screen shot of Threshold Limit

A screen shot of the wheel profile parameter flange thickness shown in Fig. 7 indicates three wheels are between the threshold limits 20 and 22. In other words, all three are below the threshold limit of this parameter. The vehicle RFID and axle sequence numbers for these same three wheels are shown in Fig. 7 in the form of a grid; this tells us where these wheels are located, i.e. which axle of which vehicle. All this information can be sent to the relevant railway maintenance stakeholders, allowing them to take the appropriate maintenance actions. In addition, data are analysed to determine how many wheels have crossed the maintenance limits set by the operator. Fig. 8(a-d) shows four wheel profile parameters, namely, flange height, flange slope, flange thickness and thread hollow, that have crossed the maintenance limits. The X-axis shows different months, and the Y-axis shows the total number of wheels that have crossed the maintenance limits in a particular month. Clearly, these data can be useful to maintenance decision-making. When we aggregate the data given in Fig. 8 (a-d) for two consecutive years, 2012 and 2013, we derive the graph shown in Fig. 9. This graph shows variation in wheel count for the four parameters, flange height, flange slope, flange thickness, and tread hollow. As the graph indicates, these wheels are over the threshold maintenance limits. In particular, Fig. 9 shows a huge variation in two parameters: flange slope and flange thickness.



(a)



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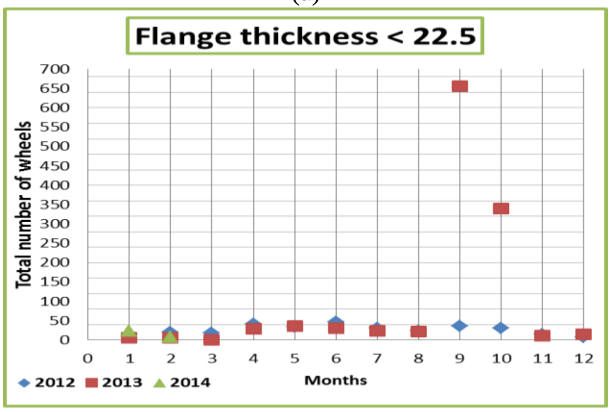

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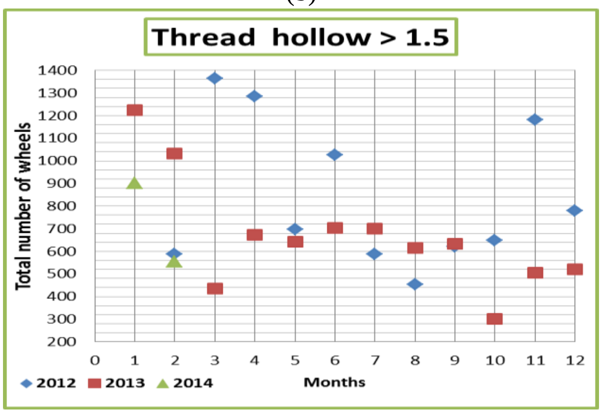

(d)

Fig. 8. Wheel profile parameters (a-d) beyond maintenance limits

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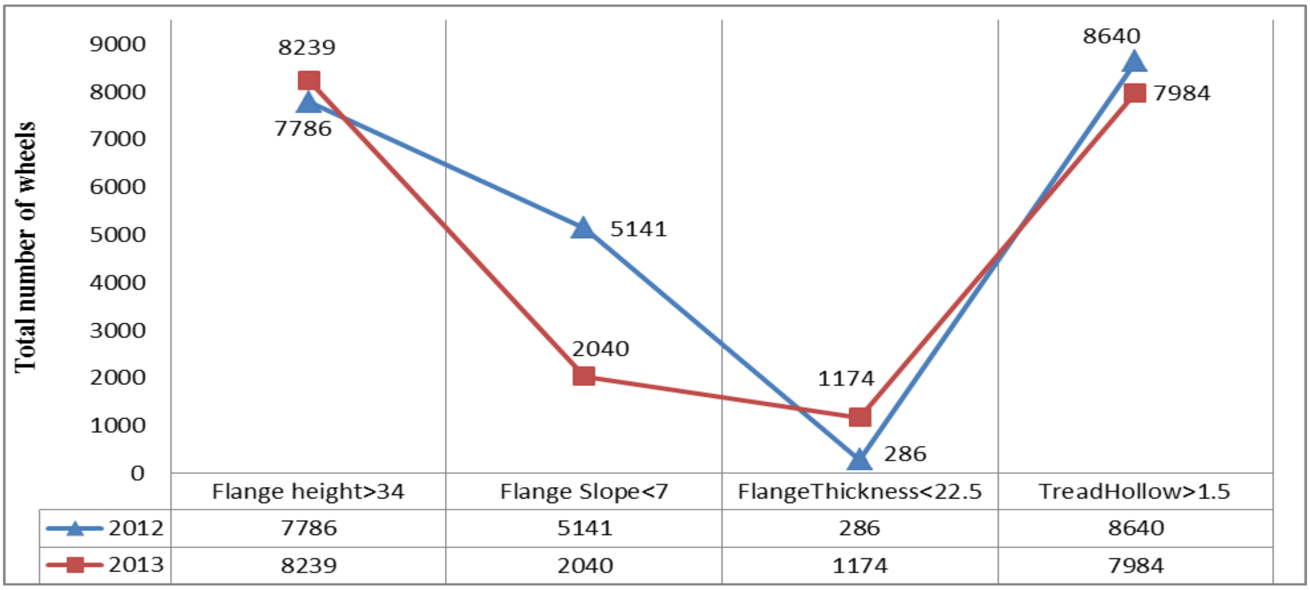

Fig. 9. Comparsion of two years of data for four wheel profile parameters

V. Conclusions

The paper shows how the cloud is used for online data analysis and how relevant information can be visualised to assist railway maintenance stakeholders in their decision-making. In this present work, the concept of web-based eMaintenance solution led the maintenance operator to make decisions for maintenance planning. In the proposed process, to enhance the performance of the maintenance process and to become more economically effective, data are acquired from way-side measurement stations and sent to the eMaintenance cloud for analysis; the relevant information, such as wheels reaching their maintenance limits, is then visualised in grids or graphs to assist stakeholders in making the appropriate maintenance decisions. The paper concludes that web-based eMaintenance solutions can be used to assist in online data analysis of railway traffic for improved maintenance.

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