Develop a new method for detailed wheel and rail roughness measurements using replica material and Dektak profilometer

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Abstract

Wheelsets are one of the most expensive components through the life of a rail vehicle. They require regular maintenance activities such as reprofiling on a wheel lathe, inspection for safety-critical damage to wheel and axle, and renewal of wheelset. There are several reasons for reprofiling such as tread wear, flange wear, and thermal; while, the cost of changing damaged rails is much greater than that of changing any other damaged part of track. The wheel and rail damage has been a concern in railway systems for several decades. The change of wheel profile and rail profile makes a large contribution to track maintenance cost. The develop a new method to measure the wheel/rail surface roughness can assist to improve the design of wheel and rail profiles, where the wheel/rail surface roughness is correlated to wheel/rail safety and economy. Therefore, the main aim of this work is to develop a new method for measuring wheel/rail roughness parameters using Dektak profilometer and replica material. The replica technique is very useful for situations in which it difficult to get to the surface in order to measure it, such as when the specimen is large; it is also useful when the components change due to wear and mechanical actions and the record of the original surface is needed. In this paper, the replica material which was applied to the wheel and rail surfaces of the twin disc test rig to make a copy of wheel and rail; then, the replica samples were measured using Dektak profilometer and the results were processed to establish wheel and rail roughness parameters.

Keywords: wheel and rail roughness, measurements, Dektak profilometer, replica material, twin disc rig.

1. Introduction to replica technique

The replica technique can be used to make a copy of the surface which needs to measure, and then; Dektak profilometer can be used to measure the surface roughness. The replica material has many types such as AccuTrans material; it has been developed for many applications such as wear and roughness measurement; and has many advantages such as: Fast and accurate even on rough surfaces, no hand mixing required, fast and easy to use, accurate dispensing, ideal for rough surfaces, flexible and accurate, horizontal and vertical planes, the setting time of regular AccuTrans is just four minutes at 20°C [1]. The replica technique has many advantages; but the most important advantage is that the replica offers a permanent history of surfaces; this record can be stored to use it for investigations at a later time. Another important advantage of the replica technique is that it can be used in places that are very difficult to access [2]. The replica technique is very useful for situations in which it difficult to get to the surface in order to measure it, such as when the specimen is large; it is also useful when the components change due to wear and the record of the original surface is needed [3]. Surface replication has been widely used in many applications such as examination and assessment of either surfaces difficult to be accessed by measurement tools or parts difficult to be dismantled for measurement. The fidelity and accuracy of the replication is one of the major concerns in actual applications [4]. The replica technique has several significant advantages, such as a permanent record of the surface being obtained, better resolution, hazardous environment is minimized, and scanning electron microscopy can be utilized [5]. The replication technique can be used to overcome many difficulties such as if there is a large wheel and we need to achieve measurements to the wheel surface, the replica technique making these measurements possible. The replication material is pressed onto the area of interest on the wheel. When the replica material is dried; it provides a surface that be identical to the surface of concern. The stylus and microscope techniques can be used for replicas measurements [6]. The replica method can be used in many applications such as hardness measurements, wear examinations, roughness measurements, and profile measurement [7].

2. DektakXT Stylus Profilometer

The measurement of various parameters of interest for a surface, including roughness, step heights or depths, by any metrology method necessarily provides only a representation of the surface details. The power of proper filtering for data analysis, according to recognized ISO standard methods cannot be underestimated when striving to provide the most accurate and reproducible results for a measuring system. Bruker has designed ISO compatibility to the two-dimensional (2D) profile ISO 4287 and 4288 standards into the versatile Vision 64TM software that powers the DektakXT Stylus Profiler. The Dektak XT (Fig 1) is a 2D contact profilometer used to provide quantitative information about step heights and surface roughness for thin and thick films measurements. This information is collected and analyzed in the Vision 64 application software. The advantages of Dektak is compatible with a wide range of materials, measures a wide range of vertical features with high resolution, and easy to use.

Fig. 1 DektakXT Stylus Profilometer

DektakXT Stylus Profilometer specifications:

Standard Operating Procedure: System Start up, adjusting the stage, taking a measurement, data analysis, and system shut down
System overview: Components (Hardware), and components (Software)
Factors: Scan parameters
Range: Vertical resolution of the scan: When measuring extremely fine geometries, the 6.5 um range provides a vertical bit resolution of 0.1 nm. For general applications, the 1.0 nm vertical resolution of the 65.5 um range is usually adequate. When measuring thick films or very rough or curved samples, select the 524 um range with 8.0 nm resolution.

Resolution: The horizontal resolution for the scan length and scan duration: the scan resolution is expressed in um/sample, indicating the horizontal distance between data points.

Speed: The scan speed in units of um/s. A slower scan generally indicates for more accurate results.

3. The twin disc rig test and replica material

The twin-disc system is simple and efficient; it consists of the use of two rollers pressed into contact, the variation of the relative velocity and of the contact pressure allows performing of the test under different conditions [8]. The twin disc approach possibly provides the best solution, and has been used extensively for wheel wear and rail testing materials [9]. The University of Huddersfield twin disc rig consists of an upper steel wheel of 310mm diameter, and a lower steel wheel with diameter of 290mm. The rollers and shafts are made of EN24T steel. Vertical force of up to 4KN can be applied on the rollers through a jacking mechanism. The rig consists of a rotary table to allow a relative yaw angle between the rollers; this yaw angle is indicated by markings on the handle of the rotary table. [10]. The twin disc rig for the University of Huddersfield (UOH) is shown in Fig (2).

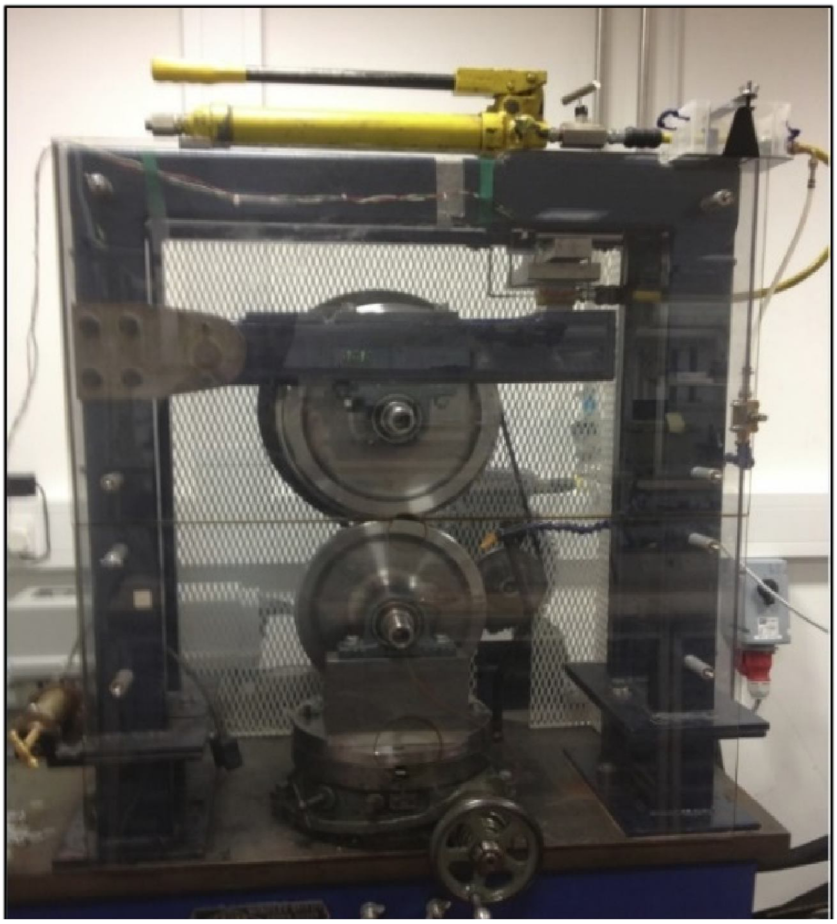

Fig 2 The twin disc rig UOH

In this work, the replica technique used for roughness measurements of the twin disc rollers, where the replica used to make a copy of the surfaces of two rollers before the test and after each test, and then the Dektak profilometer used to measure the rollers roughness. The name of the replica material which is used in this project is AccuTrans. The set of AccuTrans is shown in Fig (3).

Fig 3 The set of AccuTrans [11]

On this paper, the replica technique, twin disc rig test, and Dektak profilometer were developed for wheel and rail roughness measurements using the twin disc rig. Fig (4) shows a sample of replica material on the wheel and rail surfaces; and after the replica was taken off.

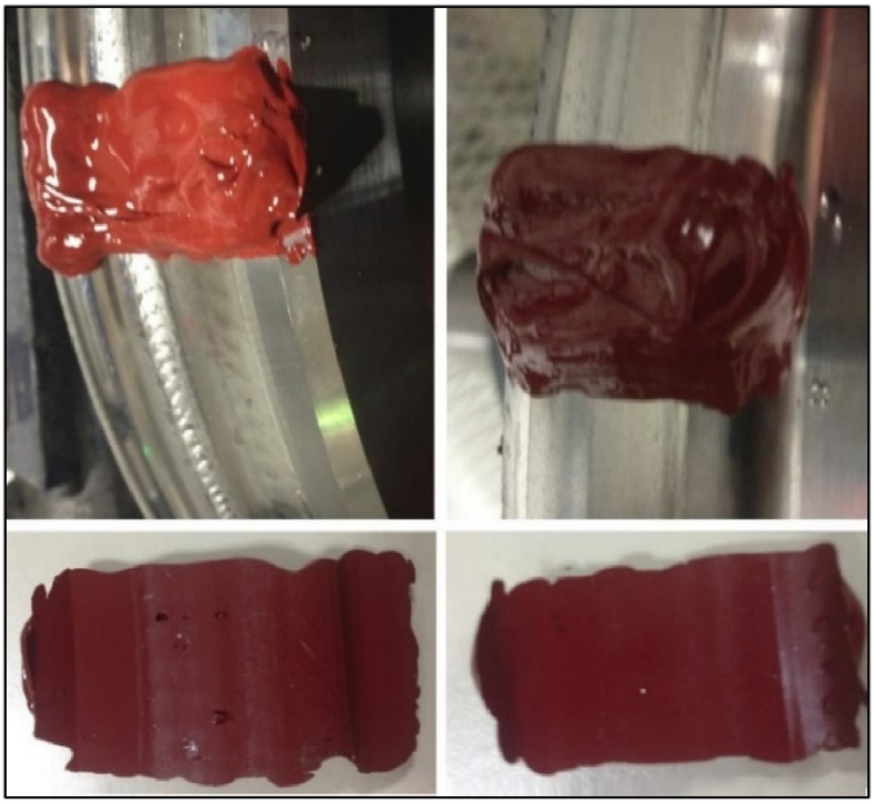

Fig 4 Sample of replica material on the wheel and rail surfaces; and after the replica was taken off

4. Surface roughness

The contact between two rough surfaces occurs at discrete contact points because of surface roughness such as shown in Fig (5). The real area is the sum of the areas of all the contact points [12].

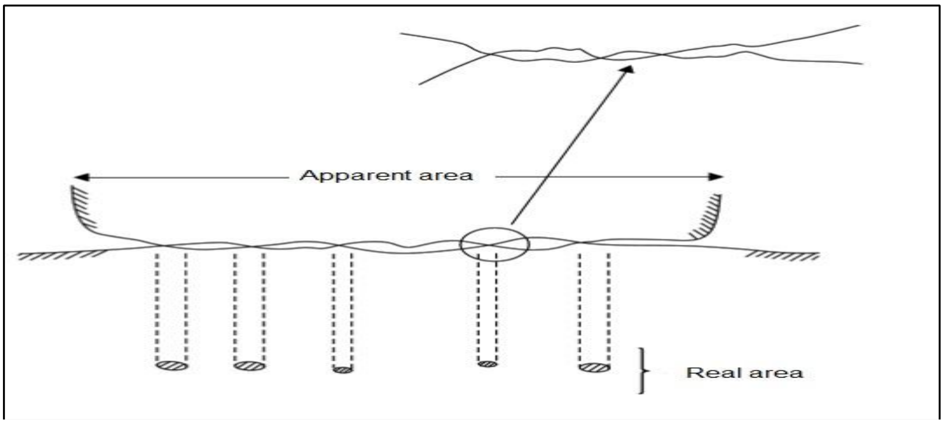

Fig 5 Apparent area and real area [12], [13]

Fig (6) shows the original profile, waviness profile, and roughness profile [14],[15].

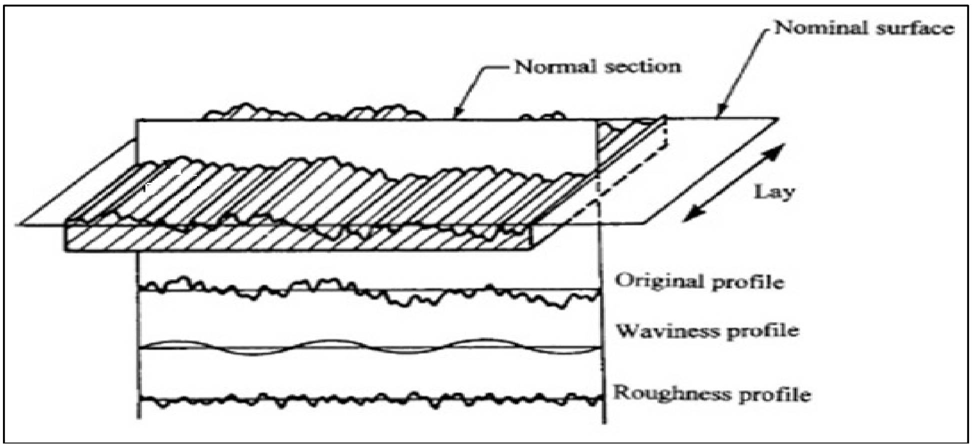

Fig 6 Original profile, waviness profile, and roughness profile [14], [15]

The basic definitions in roughness surface are [16], [17], [18]:

1. The profile can be defined as the line of crossing of a surface with a sectioning plane which is vertical to the surface.
2. Nominal surface is the intended surface.
3. Measured profile can be defined as the profile obtained with some measuring profilometers such as Talysurf profilometer.
4. Primary profile is the sum of all the deviations of the measured profile.
5. Waviness profile includes medium wavelength deviations of the measured profile.
6. Roughness profile includes only the shortest wavelength deviations of the measured profile.

The steps used to extract the roughness profile are shown in Fig (7), where low pass filter was used to extract the primary profile from the measured profile, high pass filter was used to extract the roughness profile from the primary profile, and low pass filter was used to extract the waviness profile from the primary profile. Therefore, the function of the filter is to separate the roughness profile and the waviness profile from the primary profile [15], [19].

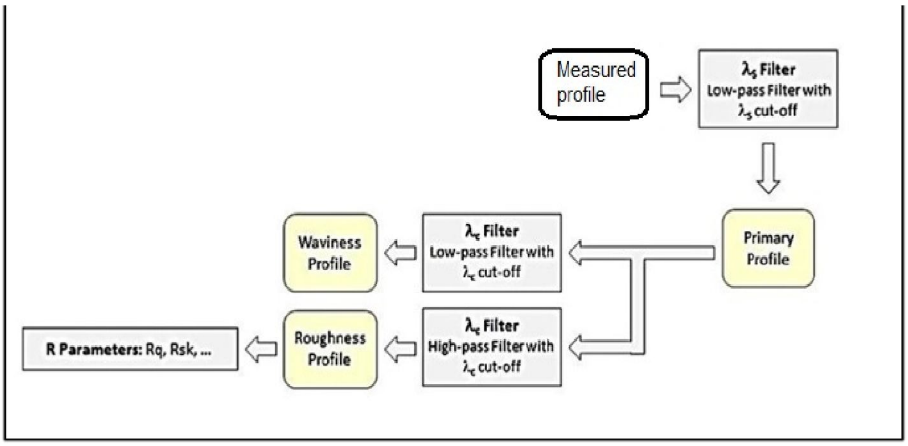

Fig 7 Extract the roughness profile and waviness profile [20]

The roughness parameters are:

1. The centre line average value (R_a) or arithmetic average roughness; it can be determined from deviations about the center line within the evaluation length such as in Fig (8).

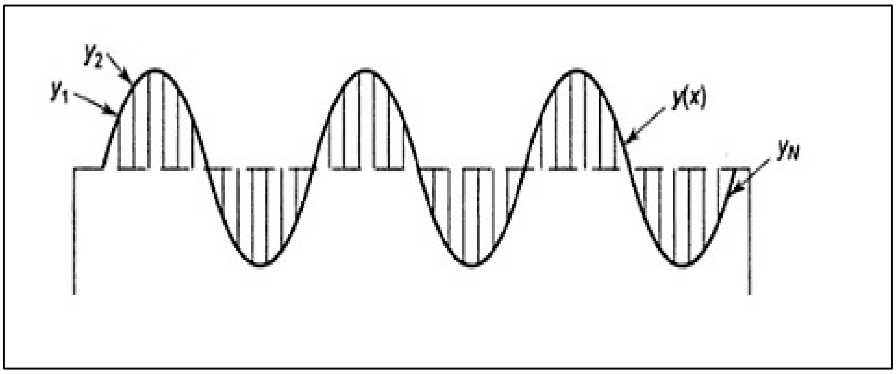

Fig 8 Surface roughness parameters [21]

The arithmetic average roughness can be calculated by the following equation [22]:

$$R_a = \frac{1}{N} \sum_{i=1}^{N} | y_i | \quad (1)$$

Where N is the total number of points and y_i is the surface profile height to the center line average.

2. The maximum deviation of a peak above the centre line (R_p); this is the value of the highest peak measured above the centerline. It is the maximum data point height above the mean line through the entire data set. It can be calculated by using the following equation [23], [24].

$$R_p = \max y(x),\ 0 < x < L \quad (2)$$

3. The maximum depth of valley below the centreline (R_v); this is the value of the lowest valley measured below the centre line. It is the

maximum data point depth below the mean line through the entire data set, and it can be calculated by using the following equation [23], [24], [25],[26].

$$R_v = |\ miny(x)\ |,\ \ 0 < x < L \qquad (3)$$

4. Maximum vertical distance (R_t), it the maximum peak to valley height of the filtered profile. It can be calculated by using the following equation [23], [24], [25], [26],[27] .

$$R_t = R_p + R_v \qquad (4)$$

5. Investigate the arithmetic average roughness (R_a) for wheel and rail using twin disc rig and Dektak profilometer.

Table (1) shows the values of arithmetic average roughness for wheel and rail after applying different values of load on rollers of the twin disc rig; where, the arithmetic average roughness was measured using Dektak profilometer.

Table 1 Arithmetic average roughness and load

Test No	Load (N)	R_a for wheel (μm)	R_a for rail (μm)
1	1000	3.53μm	2.57μm
2	1400	3.69μm	3.02μm
3	1800	3.96μm	3.24μm
4	2200	4.11μm	3.55μm
5	2600	4.19μm	3.57μm
6	3000	4.23μm	4.11μm
7	3400	4.26μm	6.13μm

Table (2) shows the values of arithmetic average roughness for wheel and rail after applying different values of yaw angle; where, the arithmetic average roughness was measured using Dektak profilometer.

Table 2 Arithmetic average roughness and yaw angle

Test No	**Yaw angle**	$\mathbf{R_a}$ **for wheel** (µm)	$\mathbf{R_a}$ **for rail** (µm)
1		2.64µm	2.85µm
2		3.15µm	3.08µm
3		3.20µm	3.45µm
4		3.29µm	3.60µm
5		3.44µm	3.95µm
6		3.94µm	5.89µm
7		4.90 µm	6.70µm

6. Discussion

A new method was developed for measuring wheel and rail surface roughness for the twin disc test rig. A replica material was used to make a copy of the surfaces of the two rollers before and after each test, and then, the Dektak profilometer used to measure the wheel and rail surface roughness parametrs. The twin disc test rig experiments were carried out to investigate the effect of key parameters such as load, and yaw angle on wheel/rail surface roughness parametrs for the twin disc test rig. Table (1) shows the values of arithmetic average roughness (R_a) for the wheel and rail after applying different values of load on rollers of the twin disc rig. For wheel surface, the R_a was equal $3.53\mu m$ at load of 1000N, and it increased to $4.26\mu m$ after applied load of 3400N. For rail surface, the R_a was equal $2.57\mu m$ at load of 1000N, and it increased to $6.13\mu m$ after applied load 0f 3400N. These results indicate that the load influence on wheel/rail roughness. These results show that the values of arithmetic average roughness were affected by increasing of load. Table (2) shows the values of arithmetic average roughness (R_a) for the wheel and rail after applying different values of yaw angle on rollers of the twin disc rig. For wheel surface, the R_a was equal $2.64\mu m$ at yaw angle of 0.1^0, and it increased to $4.90\mu m$ at yaw angle of 0.7^0. For rail surface, the R_a was equal $2.85\mu m$ at yaw angle of 0.1^0, and it increased to $6.70\mu m$ at yaw angle of 0.7^0. Therefore, there are a significant influence of yaw angle on wheel and rail surface roughness.

7. Conclusion

The University of Huddersfield twin disc test rig together with a replica technique and Dektak profilometer were developed for wheel/rail surface roughness parametrs measurements. The arithmetic average roughness (R_a) was measured for wheel and rail surfaces after each test using Dektak profilometer. Tests results show that the roughness parameter influenced by changing of load and yaw angle. The wheel and rail surface roughness can be measured using Dektak profilometer. It can have concluded that the replica material and Dektak profilometer are effective tools for the wheel/rail surface roughness parametrs measurements. The advantage of use replica material, that it is a permanent record to the wheel and rail surface roughness measurements.

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