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Assessment of Frequency on Railway Sleeper by Field Measurements and Static Analysis

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Abstract. The train is a mode of mass transportation that is fast, efficient, and relatively affordable. To support the high demand for this mode of transportation, adequate infrastructure is also needed. The condition of this infrastructure must always be monitored so that the level of security and safety of rail transportation modes can always be in optimal conditions. One important component that requires regular attention and maintenance is the railway sleepers. In this paper, a finite element (FE) model was made of railway sleepers using ANSYS software. From the analysis on the FE model, it can be explored that the deformation and stress that occurs in the railway due to loading. In this study, vibration tests were also carried out on railway based on several types of passing trains. It aims to determine the frequency value based on the type of passing train. This research is the initial stage of a series of studies on structural health monitoring procedures on railroads.

Keywords: frequency, railway sleeper, field analysis, static analysis

INTRODUCTION

Along with the times, the mode of train transportation has become an alternative in choosing public transportation in Indonesia for medium and long distances. The comfort, speed, punctuality, and more affordable prices are considerations that are the advantages of train transportation. To maintain train services, it cannot be separated from supporting infrastructure, one of which is railway and railway bridges. This research will discuss one of the efforts to maintain the quality of infrastructure services through Structural Health Monitoring (SHM) on railroads. This research is the initial stage of a series of studies related to SHM on railway. In this research, we will measure the vibration frequency of several passing train samples and also model the finite element (FE) of the railway sleepers. Several studies on SHM and FE modeling of railway sleeper models have been carried out by researchers from various countries.

Some typical data measurements vibration are given for railway structure excited by train traffic. The dominant frequency range is between 40 Hz and 100 Hz. The possibility of generating mechanisms is qualitatively described; their dependence on the most important parameters is discussed [1]. The study about a prediction model and analysis of vibration near the track also discussed with a model of a railway track on layered ground subjected to a moving train has been built and the calculation method uses Fourier transform formalism for a semi-analytical solution in the wave number domain. This study presents a sensitivity analysis of free vibration behaviors of an in-situ railway concrete railway sleeper (standard gauge railway sleeper), incorporating railway sleeper/ballast interaction, subjected to the variations of rail pad properties [2]. Through finite element analysis, Timoshenko-beam and spring elements were used in the in-situ railway concrete railway sleeper modeling. The model highlights the influence of rail pad parameters on the free vibration characteristics of in situ railway sleepers [3]. The research about the field investigation into the vibration attenuation characteristic of under railway sleeper pads (USPs), which are the component installed under the concrete railway sleepers generally to improve railway track resilience. The field trial is aimed at mitigating rail joint impacts in a heavy haul track under mixed traffics [4].

Three-dimensional nonlinear finite element model of railway prestressed concrete railway sleeper has been developed. The general-purpose finite element numerical analysis by using ANSYS 10, is employed for the numerical analyses. Using SOLID65 solid element, the compressive crushing of concrete is facilitated using plasticity algorithm while the concrete cracking in tension zone is accommodated by the nonlinear material model [5]. The application of vibration measurements and finite element model updating to the assessment of ballasted rail track sleepers, in particular with a void and pocket condition. It describes the concept of vibration measurements and the understanding into the dynamic behavior of ballasted railway sleepers [6]. The finite element model of a railway sleeper in a track system, taking into account the tensionless nature of the elastic support. The highlight is the effect of ballast distributions on the flexural responses of railway sleepers in track systems [7]. The numerical study is conducted to evaluate the load-carrying capacity of a prestressed concrete railway sleeper using LS-DYNA. The nonlinear model was validated firstly based on both theoretical analyses and experimental results in accordance with Australian Standard. Using the validated finite element model, the influences of different wear depth of RSA are investigated; and different compression strength and tensile strength of concrete and the prestress losses are highlighted [8].

MATERIAL AND METHODS

Field Measurements

In this study, a dynamic analysis was carried out on railroad sleepers when traversed by a train load by using the vibration parameters that occur on the railway sleepers. The vibrations are recorded using the accelerometer. Retrieval of vibration data using DsAcc software for Accelerometer using axis (X, Y, Z) as a parameter of the direction of vibration received by the railway sleepers. Vibration data processing uses Geopsy software to obtain frequency, amplitude and acceleration values on railway sleepers due to dynamic loads in the form of several types of passing trains.

The implementation of data collection is located at Jerakah Station, West Semarang, Semarang City. The railway elevation of +1 meters above sea level and located in the northern part of Central Java, surrounded by many catchment areas in the form of rice fields and ponds around the track as shown in Figure 1.

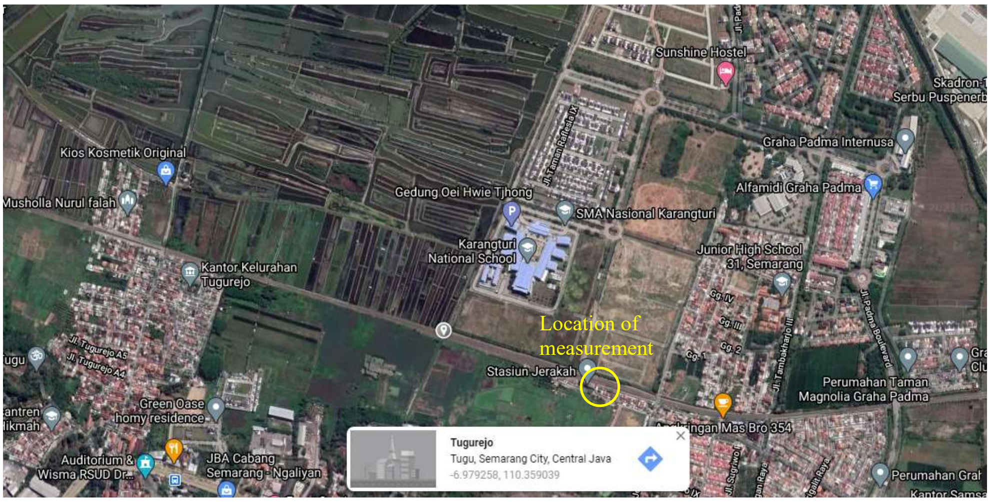


FIGURE 1. Location of study area

Materials and equipment used in this research consist of main equipment such as accelerometer (Figure 2). Supporting tools used such as roll meters, cameras, and laptops are also needed for field data collection purposes (Figure 3). Placement of sensor in railway sleeper is illustrated in Figure 2.

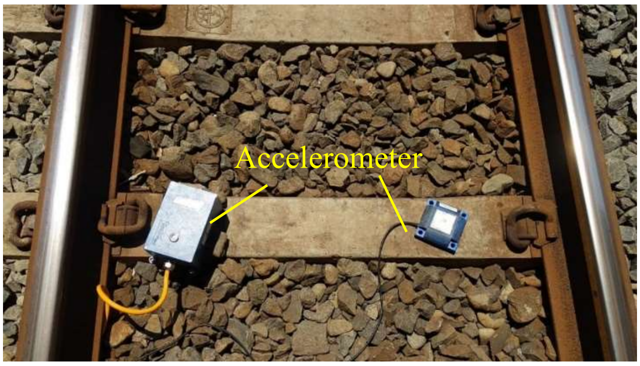


FIGURE 2. Placement of accelerometer in the railway sleeper

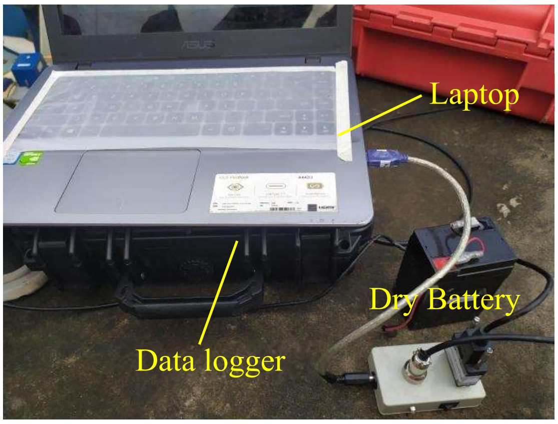


FIGURE 3. Data logger for DsAcc equipment

RESULTS AND DISCUSSION

Measurements Results

Based on data collection in the field, the velocity of train and the frequency of railway sleeper and train wheel frequency values are obtained as shown in Table 1 and Table 2, respectively.

TABLE 1. Parameter of train velocity recorded during the testing

Type of train	Train Schedule	Time (s)	Velocity	
			m/s	km/h
Joglosemarkerto	14:23	0.034	29.412	105.882
Kaligung	14:40	0.035	28.571	102.857
Argo Anggrek	13:35	0.033	30.303	109.091

TABLE 2. Frequency of railway sleeper and frequency of wheel of train

Type of train	Velocity, v (m/s)	Distance of railway sleeper, a (m)	Distance of axle, lb (m)	Frequency of railway sleeper, fb (Hz)	Frequency of wheel's train, fa (Hz)
Joglosemarkerto	29.412	0.60	8.867	49.020	3.317

Kaligung	28.571	0.60	8.867	47.619	3.222
Argo Anggrek	30.303	0.60	8.867	50.505	3.418

The acceleration of the train obtained is based on the accelerometer sensor with gravity + 2g. The data taken by the sensor produces acceleration in 3 axes (X.Y.Z axis). The results of the recorded data are shown in the following Figure 4 to Figure 6.

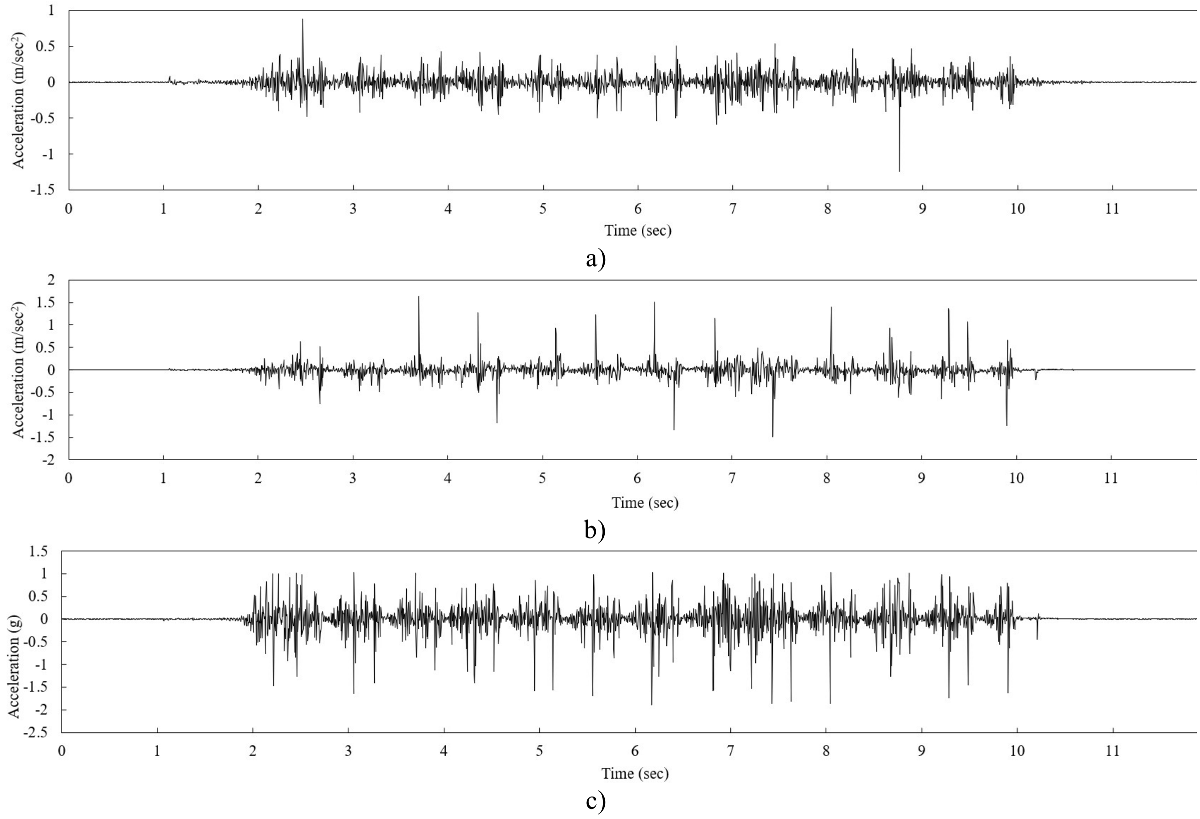
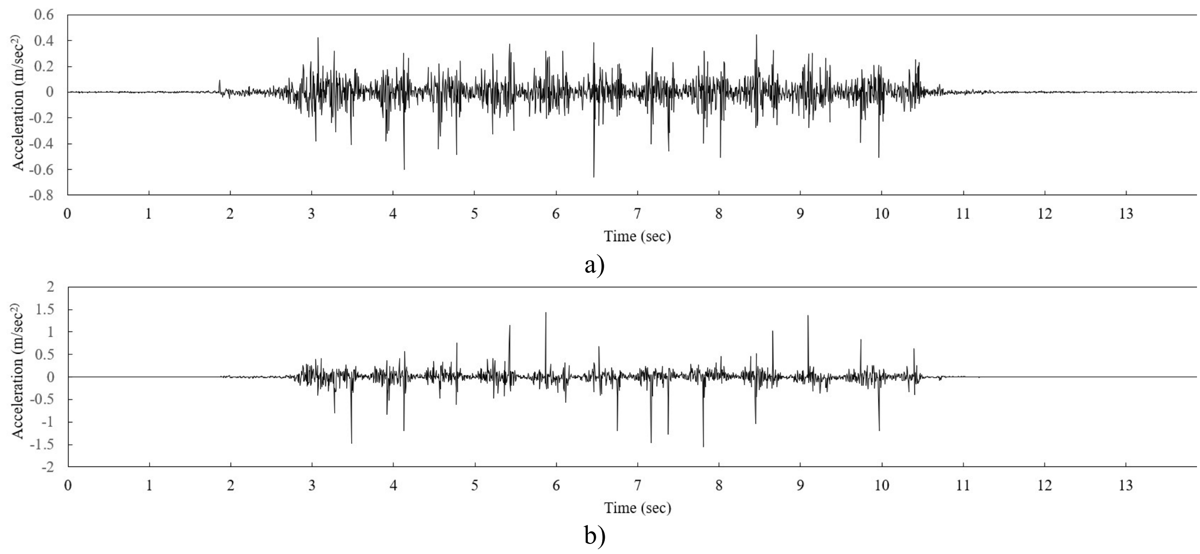
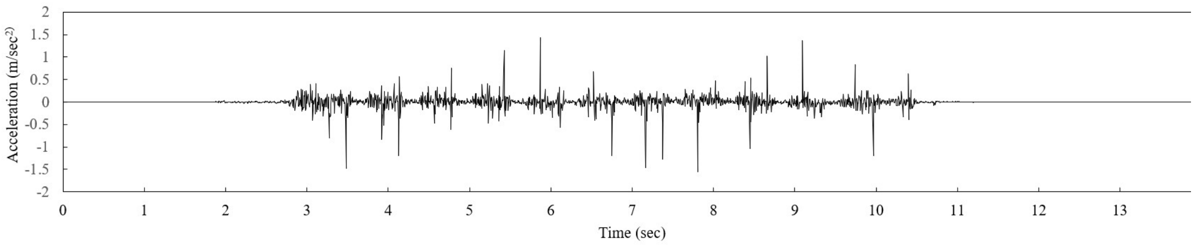


FIGURE 4. Acceleration of Argo Bromo Anggrek Train
a) X direction, b) Y direction, c) Z direction





c)

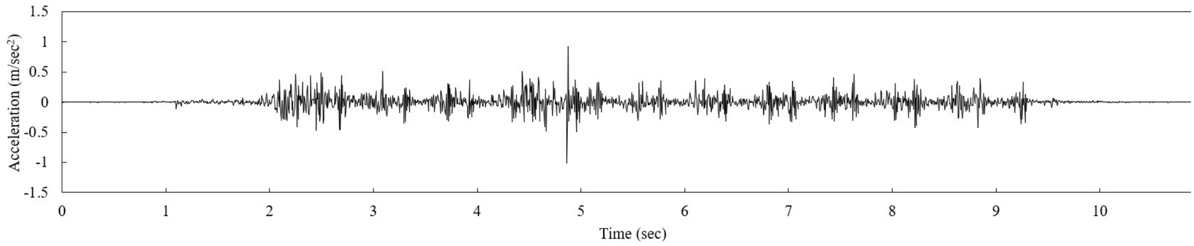
FIGURE 5. Acceleration of Joglosemarkerto Train
a) X direction, b) Y direction, c) Z direction

From the Figure 4 to Figure 6, the maximum value for each axis direction on each train is obtained as shown in Table 3.

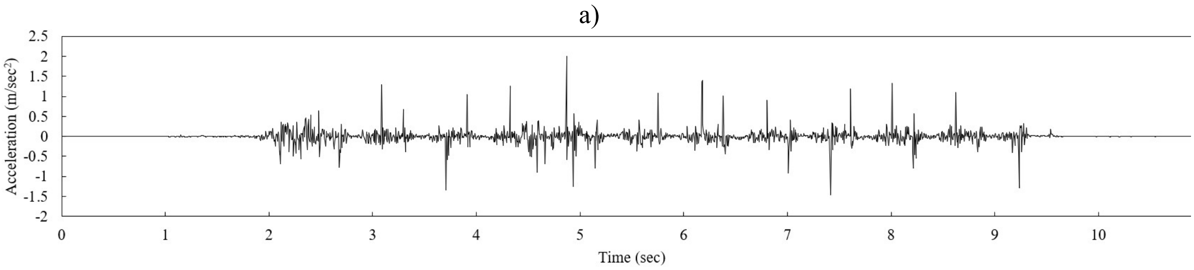
TABLE 3. Maximum acceleration for each type of train in each axis

Type of train	Acceleration		
	X	Y	Z
Joglosemarkerto	0.445	1.433	1.030
Kaligung	0.920	1.999	1.063
Argo Anggrek	0.885	1.632	1.034

From the results seen in Figures 4 to Figure 6 and Table 3 concluded that the largest acceleration is the Kaligung train, followed by the Joglosemarkerto train, and the smallest is the Argo Anggrek train for the three directions X, Y and Z.



a)



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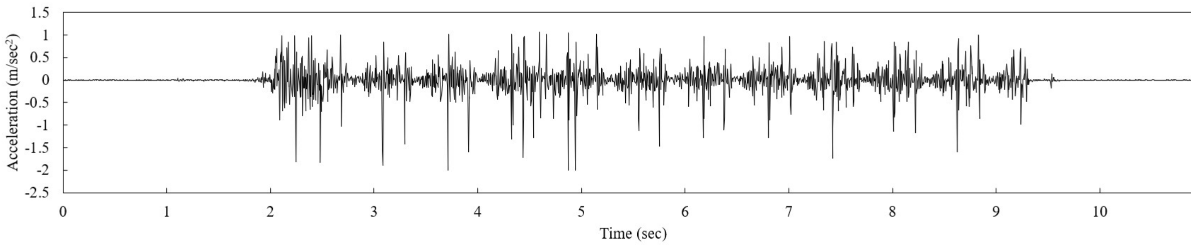


c)

FIGURE 6. Acceleration of Kaligung Train
a) X direction, b) Y direction, c) Z direction

From the figure above, the maximum value for each axis direction on each train is obtained as shown in Table 3.

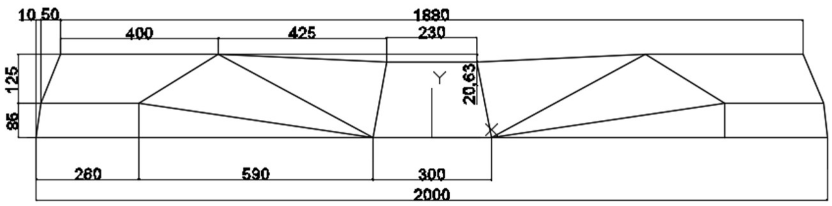
TABLE 3. Maximum acceleration for each type of train in each axis

Type of train	Acceleration		
	X	Y	Z
Joglosemarkerto	0.445	1.433	1.030
Kaligung	0.920	1.999	1.063
Argo Anggrek	0.885	1.632	1.034

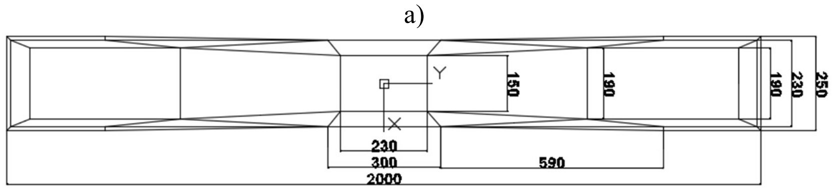
From the results seen in Figures 4 to Figure 6 and Table 3 concluded that the largest acceleration is the Kaligung train, followed by the Joglosemarkerto train, and the smallest is the Argo Anggrek train for the three directions X, Y and Z.

Finite Element Model of Railway Sleeper

Modeling using Ansys R1 2020 is carried out with bearing specifications used type N-67. The quality of the material used is concrete K 500kg/cm2 or Fc' 41.5 MPa and UTS reinforcement 15462kg/cm2



a)



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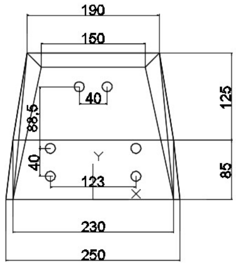
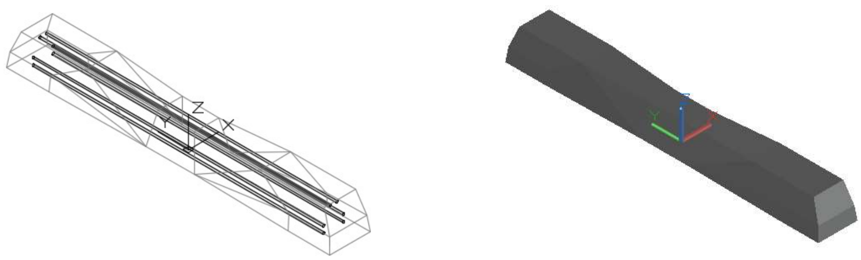
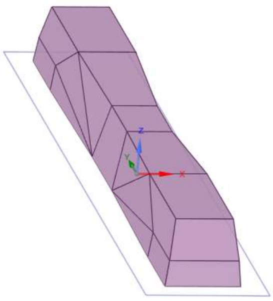


c)
FIGURE 7. Sleeper Railway with a) Front view, b) Top view and c) Side view



a) b)



c)
FIGURE 8. Finite Element model of sleeper railway
a)Reinforcement, b) 3D view, c) Undeformed

Based on the modeling that has been done using Ansys R1 2020, it produces an analysis of sleeper strength. These results become a reference for the condition of the bearings currently installed in the field. Based on the results of the analysis, deformation is obtained as shown in Figure 9. The modeling results show that the deformation in the X direction is 0.0006898 mm, the Y direction is 0.00139 mm, and the Z direction is 0.0065 mm. From the comparison of the results in the three directions, it will be discussed in more detail about the distribution of displacements that occur in the Z direction. The displacements that occur in the Z direction range from 0 to 0.006 mm. The center of the sleeper railway dose not experience displacement as shown in blue. Displacement will increase from the center of the sleepers to the ends of the sleepers like the contour color in the picture. The increase in displacement starts from the smallest in blue. Then it gradually increases according to the color change from light blue, green, yellowish green, light yellow, dark yellow, orange and red. The part that experiences the largest displacement in the Z direction is the position of the rails at both ends of the sleepers shown in red. In this section the amount of displacement that occurs ranges from 0.0058 mm to 0.0065 mm.

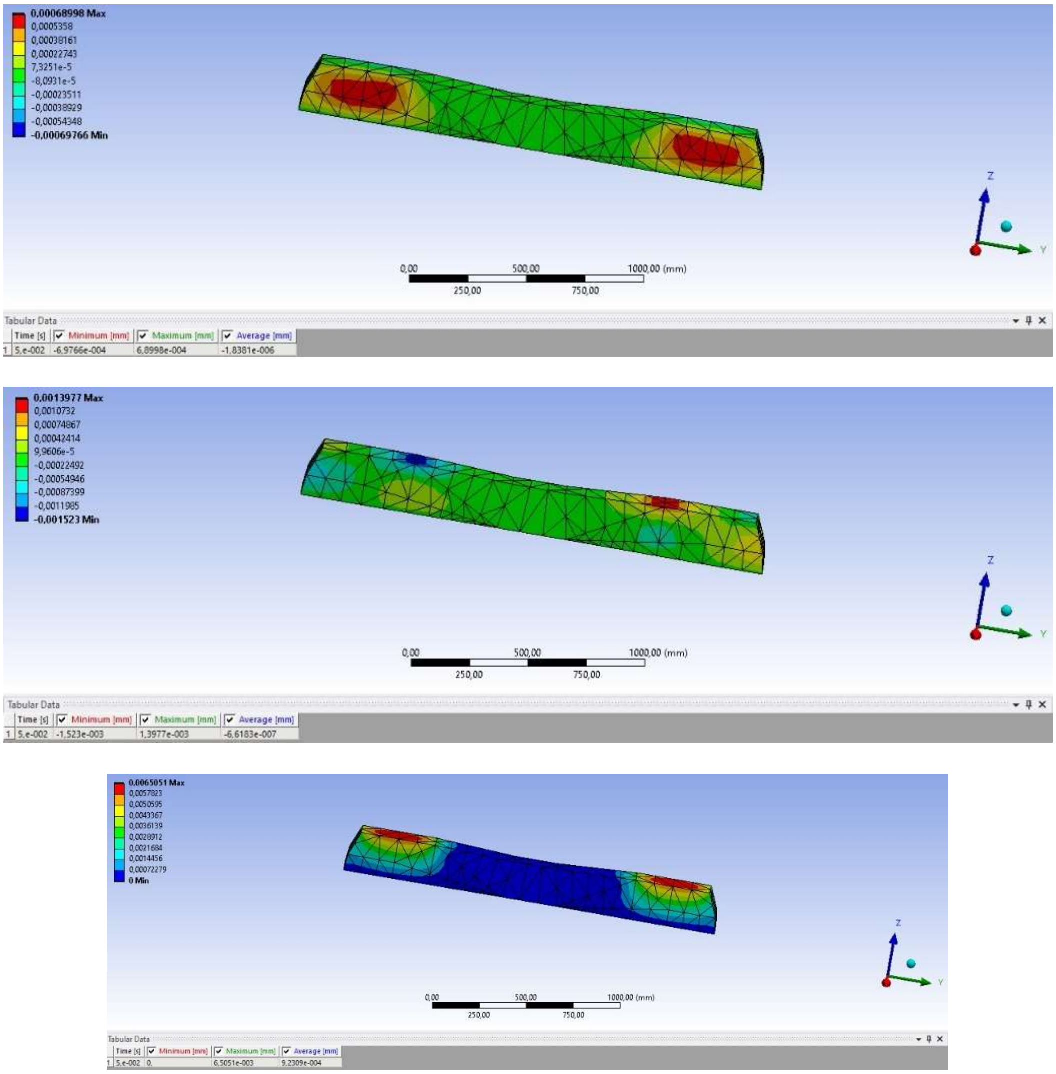


FIGURE 9. Deformation of sleeper railway

In addition, it can also be seen in the equivalent stress or equivalent stress in Figure 10. In Figure 10 illustrate the stress that occurs is in the interval from 0.0014 MPa to 1.022 MPa. In the middle of the sleeper, blue means that in that area experience less stress than in other parts. The stress that occurs in the middle of the rail sleeper is around 0.0014 MPa. The stress increases from the center of the bearing to the left and right ends of the bearing. The increase in stress is indicated by a change in the color of the voltage contour from the smallest to the largest, starting from dark blue, light blue, light green, dark green, yellow, brown and red. The position of the rails on the sleeper shows stress values ranging from 0.795 – 0.909 MPa or shown in brown. In that section there is a small portion that has a stress between 0.909 MPa to 1.022 MPa or shown in red.

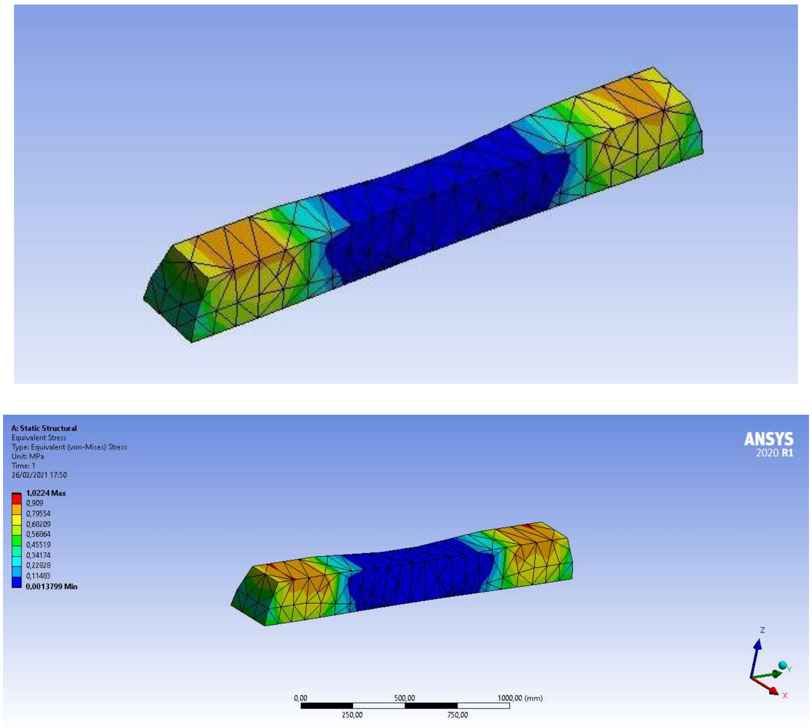


FIGURE 10. Equivalent Stress of sleeper

CONCLUSION

The data obtained based on the accelerometer sensor produces a maximum vibration acceleration or acceleration on the X axis of 0.92m/s^2, namely when it is crossed by the Kaligung train. The maximum vibration acceleration on the Y axis is also 1.99879m/s^2 when it is crossed by the Kaligung train. And the maximum acceleration or vibration on the Z axis is 1.06256m/s^2 when it is crossed by the Kaligung train.

The modeling results using Ansys R1 2020 show that this sleeper has a deformation in the X direction of 0.0006898 mm, the Y direction of 0.00139 mm, and the Z direction of 0.0065 mm with assuming that the load on the sleeper is in accordance with the maximum rail load specifications.

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