Standardized Concept Design of Structural Testing and Camber of Railway Flat Wagons

Hary Soebagyo [1*], **Arif Riyadi T.K** [1]

[1]*Jurusan Teknik Mesin, Universitas Pancasila, Jakarta Selatan, Kode Pos, Indonesia*
**Email Corresponding Author: hary.soebagyo@univpancasila.ac.id*

ABSTRAK

Kereta api merupakan salah satu sarana transportasi massal yang berfungsi untuk mengangkut manusia maupun barang. Mengingat fungsinya yang penting maka keandalan dan keamanan kereta api harus dijaga selama beroperasi terutama bagian strukturnya yang harus kuat dan andal dalam menerima beban yang diembannya mengikuti ketentuan RAMS (*Reliability*, *Availability*, *Maintainability*, *Safety*). Bagian struktur utama yang menjadi perhatian adalah kerangka bawah gerbong kereta api yang fungsinya untuk menopang seluruh beban yang diterima. Desain struktur kerangka bawah ini dibuat sedemikian rupa agak melengkung agar ada beban pre-stres yang dapat menahan beban bending saat struktur terbebani. Desain struktur yang sedikit melengkung ini disebut "carbody camber" dimana camber tersebut didefinisikan sebagai jarak terendah antara titik tengah bentangan struktur gerbong terhadap titik tumpuan. Mengingat pentingnya struktur gerbong dan cambernya tersebut maka perlu dibuat standar pengujian struktur dan pengukuran camber yang baku untuk industri kereta api di Indonesia. Makalah ini membahas kajian tentang bagaimana penyusunan konsep rancangan standar metode pengujian dan pengukuran nilai camber yang mengacu pada standar Internasional dan peraturan perundangan yang berlaku di Indonesia. Hasil kajian berupa konsep desain yang berisi metode dan tahapan langkah-langkah pengujian struktur dan pengukuran camber kerangka bawah dari gerbong datar kereta api. Konsep ini dapat dipakai sebagai bahan awal untuk menyusun standar nasional dalam pembuatan struktur kerangka bawah kereta api.

Kata kunci: metode; camber; struktur; kerangka bawah kereta api.

ABSTRACT

The train is a means of mass transportation that functions to transport people and goods. The level of train safety must be maintained during operation, especially the structural parts which must be strong and reliable in accepting the loads they carry following RAMS provisions (Reliability, Availability, Maintainability, Safety). The main structural part of concern is the lower frame of the train carriage whose main function is to support all the loads received. The design of the lower frame structure is made in such a way that it is slightly curved so that there is a pre-stress load that can withstand bending loads when the structure is loaded. This slightly curved structural design is called "camber" where camber is defined as the lowest distance between the midpoint of the span of the carriage structure and the fulcrum. Considering the importance of flat carriage structures and their camber, it is necessary to create standard structural testing and camber measurement standards for the railway industry in Indonesia. This paper discusses how to develop standard concepts for testing methods and measuring camber values which refer to international standards and applicable laws and regulations in Indonesia. The results of this study are in the form of a design concept containing methods and stages for testing of the lower frame structures and measuring the camber of the lower frame structures of the train. This concept can be used as initial material for developing national standards in the manufacture of the lower frame structure of the train.

Keywords: method; camber; structure; underframe of the train

INTRODUCTION

One of the safe and widely used mass transport vehicles in the world is the Railway. This means of mass transportation functions to transport both humans and goods in large quantities. According to its function, the train is classified into 2 (two) parts, namely passenger trains and freight trains [1]. For freight trains, there are several types of freight trains that are numerous and commonly used, namely the so-called flat wagon or flat wagon (Figure 1), this freight train is in the form of a flat plane, generally used to transport cars, sheet steel, roll steel, profile steel, containers, wood, and others.



Figure 1. Flat Wagon Hopper

Another type is the hopper wagon, this freight train has one place where the top is open, and the side can also be opened, usually used for transporting coal, wood, iron ore, and others (Figure 2).



Figure 2. Hopper Wagon

In addition, there are also other types, namely tanker wagons, this freight train is in the form of a tank and is generally used for transporting liquid or fluid goods (Figure 3).



Figure 3. Tanker Wagon

There is also another type, namely the well wagon, similar to a flat wagon, but the center of the wagon is made a basin to place goods (Figure 4).



Figure 4. Well Wagon

By paying attention to its function and workload where safety is the most important thing, especially during its operation, where the train must have a strong and reliable structure. The design and manufacture of trains must pay attention to many aspects, including reliability, availability, maintainability, and safety, known as RAMS [2,3]. Furthermore, in order to ensure its strength and reliability, the train must go through a good work process through systematic stages through a careful design or planning process, using standard standards, and going through an experimental testing process to validate the design results. This also applies to all railway components including important and critical parts such as the lower frame structure, both for trains (for transporting people) and carriages (for transporting goods). In terms of the structure of the lower frame, there needs to be more attention because it is the basis of all the loads received by the train. For this reason, it is necessary to add or extra strength by giving a slight curve to the structure, namely with what is called the 'cambering' process. Camber (carbody camber) is defined as a vertical curved shape that is seen from the side in the form of an arc shape from end to end of the carbody structure. This camber is the lowest distance between the midpoint of the carriage structure stretch to the focal point [4-6]. The function of this camber is as a pre-pressed load that helps the structure receive the bending load that comes from the load of goods received by the train or train car. In this discussion, what was observed and became the focus of the study material was cambering on the lower frame structure of a flat train car, flat cars were chosen because the structure was seen as relatively simpler and relatively easy to analyze, and could be applied

in general both for trains and train cars. So, in general, it can be said that the making of camber or so-called "cambering" must pay attention to the function of the structure and also pay attention to the purpose of the camber [4].

Please note that currently there is still no standard that requires camber for the basic frame structure of the railway. For this reason, for the sake of railway safety and security, it is necessary to prepare standards for testing the mechanical strength of the structure and camber measurement of the lower frame of the railway using standard and official national methods and standards that will be issued by the Government. This research or study produced a concept design for the standardization of structural testing and camber measurement of railway cars as material that can be included in the Indonesian National Standard (SNI).

RESEARCH METHODS

The methodology carried out for this research or study is by studying literature or literature study, especially from international standards that are commonly used in developed countries and also studying the rules that have been made by the authorized Government institution, in this case the Ministry of Transportation. Government regulations of a railway manufacturing country will be the main reference because licensing and assessment of the feasibility or unsuitability of a railway is the authority of the institution, namely the Regulation of the Minister of Transportation of Indonesia [7,8]. Literature studies are commonly used in scientific activities to obtain data and information to support the solution of the problems faced [9,10]. In this case, the case is done by taking the example of one type of train, namely a flat car. Flat carriages have been chosen in this case to simplify the flow of thought due to their relatively simple shape. The research methodology can be outlined following a flowchart as shown in Figure 5. The research began by conducting a literature study on the camber of the lower frame of the railway frame car. Camber is a requirement in the design of the lower frame structure of railway cars and must be applied to all types of carriages and types of trains used to transport goods and passengers [4,11]. All the prevalent standards can be used in railway research and testing, namely the IUC, JIS and Ministry of Transport Regulations, as well as several other documents related to structural testing and assessment of the lower frame camber of railway cars [9,10].

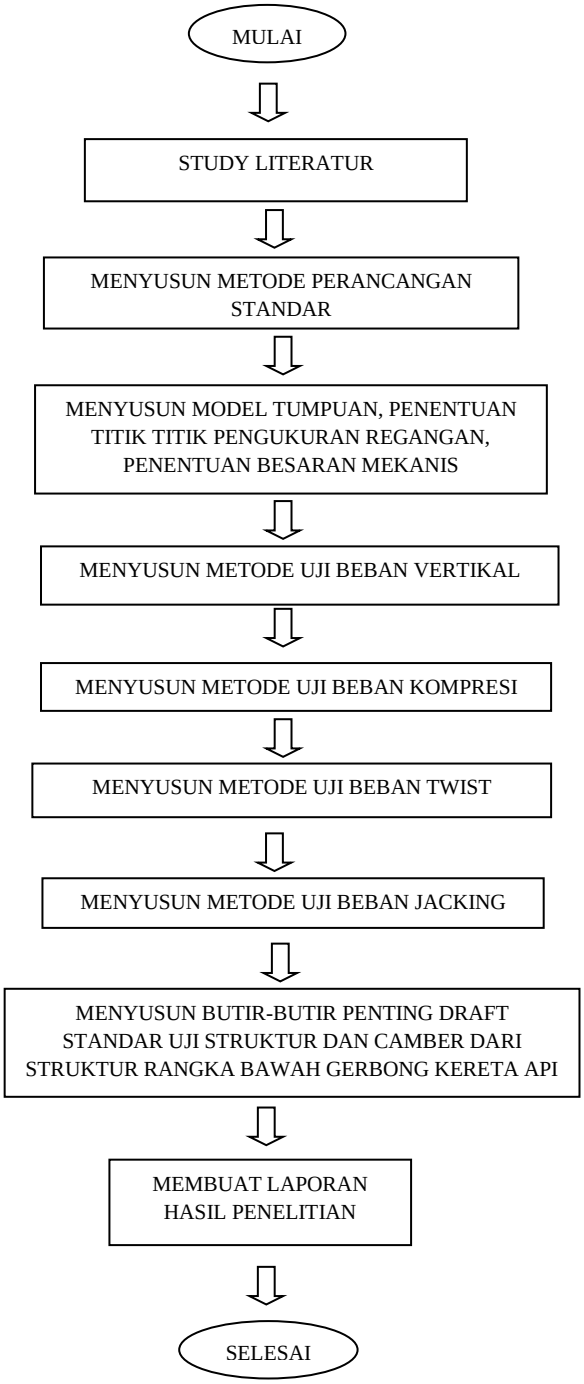


Figure 5. Research activity flow chart

Any structure that is subjected to bending loads, should be designed to provide a camber of a certain amount, as well as the structure of this railway flat car. Camber as illustrated in Figure 6 is defined as the lowest distance between the midpoint of the span of the carriage structure to the point of the fulfillment.

The requirements of the design of the railway structure require that camber always have a positive value even when loaded with maximum loads. Positive camber means that the camber value must be above a straight line between the pears [4]. The camber of the lower frame structure of the railway car which is a vertical curve shape in the form of an arc from end to end of this structure must have a positive camber that does not exceed (1/2000) of the length of the car body and be under empty conditions without load. Then the carriage structure is conditioned and designed in such a way that it is in full load condition (normal load) and throughout its operation there should be no negative camber. The maximum difference between the camber of each side of the "sill" measured from its maximum deflection shall not exceed 0.125 in. For approval in the planning of the railway car structure, the results of the measurement of the value of the camber in 3 conditions must be shown, namely in the condition of zero load, the condition of full load, and the condition when a collision occurs. [4].

By referring to the existing rules and standards of railways, it is necessary to test the camber of the lower frame of the railway car. For this reason, it is necessary to design a standard testing and measurement procedure, as well as make it a national standard in accordance with the capabilities and capacity of railway manufacturers in Indonesia.

The next stage of the study activity can be continued by designing a procedure for testing and measuring the camber of the lower frame of the carriage followed by making a loading simulation given to the structure of the lower frame of the railway car which is carried out by considering the properties of the material used. In general, the material used is steel with special qualities for the structure of the lower frame of the railway [4, 12-14]. Furthermore, planning is carried out to prepare a focus model, determination of strain measurement points where it is estimated that a large voltage is at that point, and determine the mechanical quantity with the parameters of force, strain and deflection that will occur.

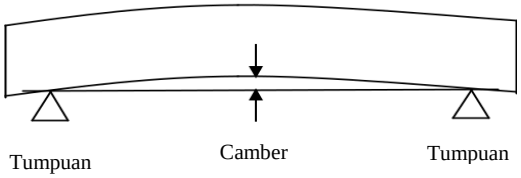


Figure 6. Camber of the frame structure

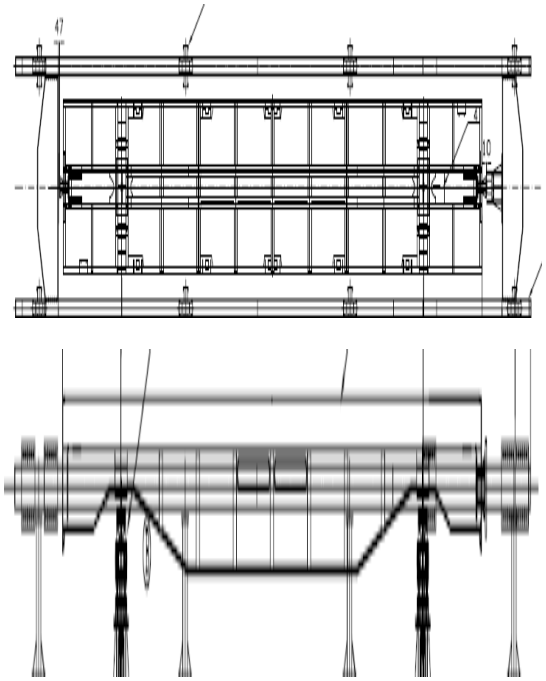


Figure 7. Schematic Illustration of a Flat Car

Figure 7 provides a schematic illustration of flat carriages [7,8]. The next stage is to design various types of loads that may arise or occur as during operation, namely vertical load test stages, compression load tests, twist load tests, and jacking load tests, which are loads that simulate repairs in the event of repairs or during emergency conditions. Furthermore, important points of the Draft Camber Test Standard for the Lower Frame Structure of Railway Cars were designed and formulated. This stage is the final stage for the preparation of procedures and stages of the conception of camber measurement of railway structures. Finally, a study report was prepared from the concept of standard railway structure measurement as an obligation for accountability for activities.

RESULTS AND DISCUSSION

From the literature study related to camber testing for railway flat car structures, especially from the IUC standard and the European Structural Steel Standard EN 10025:2004, as well as regulations from the Ministry of Transportation, it can be known the methods, testing and measurement stages for the camber of flat car lower frame structures that are commonly used according to their research results and according to their needs. There are technical guidelines for making a model of the base in camber tests and measurements that can be referred to and applied to the design of national standards later, Then there

are various variations of loading that are prevalent and feasible to apply because in practice the operation is often experienced by railways. Vertical loads, for example, this load must occur when the train is transporting people or goods, This load is received by the structure of the lower skeleton of the carriage directly in a vertical direction whose magnitude depends on the weight of the object being loaded. Meanwhile, there is a load called a compression load, which is a load that must be taken into account because it occurs due to the process in which the carriage structure is overloaded when there is acceleration, deceleration, and coupling between carriages. Various literature also states that this burden must also be taken into account because the frequency of its occurrence is very frequent. In practice, the train is not always smooth and smooth in its operation, if it is damaged or if there is an emergency, there needs to be repairs in the workshop. In the workshop, the structure of the flat carriage will undergo repairs by lifting the body using a lifting device or jack in such a way that the train body will be lifted in a position that makes it easier to make repairs, this also causes the occurrence of a load that needs to be anticipated. In addition to the three loads mentioned above, there is still one additional load that also needs to be taken into account, namely the twist load. This twist load is a twist load that occurs during repairs either in the workshop or on the railroad during an emergency when there is damage to the bogie or railway wheels.

In addition to observing and studying the loads that arise and act on the structural undercarriage of the train, the design of the test standard also takes into account measurements of the mechanical magnitudes that occur during the test. So, this standard also covers how the measurement process should be carried out at the time of testing. Several important parameters need to be measured and observed in magnitude, such as the paraneter of strain and deflection that arises during the loading process, both during vertical loading, compression, twist and jacking. Various literature states that the measurement method uses sensors such as force sensors using load cells, strain sensors called strain gauges and also deflection sensors known as deflection meters or displacement transducers.

An explanation of the results of observations of the loading procedure method and measurement procedure from the literature and will be adopted for the design of the standardization of the camber test of the lower frame structure of the railway can be described as follows.

3.1 Focus Modeling

Railway cars are generally supported by wheels using 1 set of series consisting of various components or parts of the railway system, namely bogie, bolster, swing arm, and wheels. The structure of the carriage is connected by a series of bogies by means of a bolster [4,15]. For the testing of the structure of the lower frame where the load is given a vertical direction, the position of the focus is set at the right point on the bolster is located. The base at this bolster point is a support system that occurs between the structure of the carriage and the bolster is a support that allows two directions of movement, namely longitudinal movement and rolling movement. For this reason, the base model in the vertical load test of the railway car is determined with a roller support model to avoid any moments that occur on the base, so that the support only allows longitudinal and rolling directional movements.

Meanwhile, for the longitudinal directional support system where there is a compression load in the connection position between the carriages, which is located at the knuckle location. Then one end of the knuckle is connected to a fixed base and the other is connected to compression load generation equipment which is generally a hydraulic machine that can provide relatively strong force.

3.2 Weighting and Measurement Principles

In real operations in the field, railway cars will experience various loads due to the contour of the rail surface, the speed of the train, the size of the load, sharp and twisting bends, and imperfect damping systems, or in the event of an unexpected accident. There are many models that can be chosen as frequent loads and are very likely to occur during the operation of the train. However, there are several types and models of these selected loads that can be classified into various main types, namely:

- Vertical load, this load is the result of the weight of the carriage's load in the form of passengers and goods.
- Compression loads, compression loads arise due to the acceleration and slowdown of the train speed and due to the process of connecting or coupling the carriages.
- Twist load, which is a load that is considered to be able to occur during an emergency, for

example there is damage to one of the wheel systems.

- Jacking load, this load was chosen because it takes into account the load that arises due to the maintenance and repair process of the carriage that occurs in the field.

The principle of charging can be explained in essence by the method as below, which is the main thing in making the concept of standardization of a new product issued by railway manufacturers and is the main requirement for whether or not this railway product is suitable to be operated and used by the public. This standardization is an effort to guarantee the public in order to maintain the safety and security of its use.

3.2.1 Vertical Load Test

As a simulation of the carriage structure test due to its function as a means of transportation, a vertical load test was carried out. This vertical load test simulates the load due to the presence of a load in the form of people or goods that weigh the structure of a railway car. There are vertical loads that are supported in 2 conditions, namely the empty load condition (tare load) and the full load condition (full load). The empty load condition simulates the condition where the train is empty (without load), so that the load of the empty condition is only in the form of components that are on top of the structure of the lower frame of the car. The second condition is the condition of full load, meaning that the carriage structure receives the maximum load that is planned to be able to be supported by the carriage structure. Loading is carried out by weighing the structure of the carriage where the load is placed on the carriage and distributed evenly.

3.2.2 Compression Load Test

Due to the acceleration, deceleration, and coupling process between carriages, it is necessary to have a compression load test to simulate it. There is a requirement of the International standard for the design of carriage structures regarding the amount of compression where the stress should not exceed 90% of the yield voltage. Meanwhile, according to the regulation of the minister of transportation, the structure of the carriage must be able to withstand compression loads with a voltage that must not exceed 75% of its yield voltage. The compression load test of this carriage structure is divided into 2 (two) conditions, namely:

- Compression loads with vertical loads in an empty state.
- Compression load with vertical load in full condition.

3.2.3 Jacking Load Test

Simulation of the carriage structure when repairs are carried out in the workshop or in the event of an emergency in the field, it is necessary to carry out a load test called a jacking load test. Repairs in the workshop are simulated with the condition of the vertical load in an empty state, while the simulation in the field is carried out with the maximum vertical load condition, the trick is to lift the two jacking points so that the carriage structure is lifted until there is a load at the location of the bolster base point.

3.2.4 Twist Load Test

Simulation of the condition of the carriage structure if it experiences twisting loads that occur during repairs or emergency conditions due to damage to rails, bogies and wheels is carried out by twist load test. The trick is to load the carriage structure through a vertical load in an empty state and the focus system works with only 3 focus points from 4 jacking point locations, so that there is a twist or twist load on the carriage structure.

3.2.5 Camber Measurement

Meanwhile, for camber measurement, in principle, the purpose of this camber test or measurement is mainly to determine the deflection of the width of the carriage either in a loaded condition due to a load supported by the carriage or when the load is removed again or in a condition of the load being unloaded. This can also apply to new carriages made with reference to the EN 12663-2:2010 standard.

For this camber testing can be given a schematic illustration of the testing and camber measurements of the lower frame structure of the railway car (Figure 8). The figure shows that the distance of the left axis to the ground level is R1 and the distance of the right axis to the base level is R2. Meanwhile, the distance from the bottom of the carriage to the ground level is F exactly in the middle position, measured and recorded its value both when the condition is empty or unloaded and when there is a load or load given.



Figure 8. Schematic Testing Principles

In fact, train operations sometimes encounter many things during the transportation process, because in reality there are various kinds of products or commodities that are transported and cannot provide uniform load loads, the distribution of the load is uneven. For this reason, sometimes it is also necessary to have a combination of product or goods placement and sometimes also cause eccentric loads to be transported. In this case, attention is needed to the torsional load and certain limitations are needed and data from tests or results from camber measurements due to uneven load distribution to avoid unwanted things to the main railway bogie during its very dynamic operation. Another thing that needs to be considered is the possibility of wheel tilt, especially from the vertical direction when viewed from the front of the train. When the wheel tilts out at the top, the camber is positive, when it tilts inwards at the top the camber will be negative. The magnitude of the slope is expressed in degrees taken from the vertical direction. This camber arrangement is important because it affects the control of direction and wear of the rail's wheels. A high positive camber value can result in premature wear on the outside of the wheel and it will cause excessive wear on the suspension of the railway car. The same is true of large negative camber values, which can result in premature wear on the inside of the wheels and can also cause excessive wear on the inside of the wheel suspension system of the railway car. Camber from side to side that is not equal by 1° or more will be able to cause the carriage to pull or steer to the side with the most positive camber. For this reason, it is necessary to pay attention to the results of the torque test and pay attention to the camber test procedure.

3.2.6 Mechanical Quantity Measurement

The main purpose of the test activity is to measure and observe a quantity or parameter. In the testing of the carriage structure, the parameters measured are load (force), strain and deflection. Strain and deflection parameters are measured at each stage of the test for vertical load, compression, twist, and jacking tests. Meanwhile strain is used to calculate stress as a basis in the evaluation of structural strength. Strain is measured using a strain gauge. To get optimal results, strain measurements are carried out on critical parts of the carriage structure, namely in areas that are estimated to be very critical or areas that experience relatively very large stress. While the strain sensor is installed at the measured point by gluing, so that the movement or strain that occurs at that location can be measured by the strain gauge. The output of the strain sensor in the form of an electrical signal is equivalent to the voltage equivalent to the amount of strain (elongation) of the test object, then the data is recorded using a data logger. Furthermore, to find out the change in camber value, especially because vertical loads are used using linear variable displacement transducer or LVDT equipment, which then the results are also recorded with a data logger.

3.3 Standard Concept of Railway Flat Car Lower Frame Structure Test

From the analysis carried out and observing the methods that must be carried out, the formulation of this research or study is obtained, namely in the form of the concept of the Standard Content of the Lower Frame Structure of the Railway Flat Carriage. This test standard is general, meaning that it is quickly proposed to be applied to structural testing and camber re-measurement (recambering) of railway underframe structures that have been repaired or retrofitted. The important points of the standardization concept are as follows:

1) **Introduction**

   This introduction contains, among other things, the importance of the safety of train travel to transport passengers and goods, ensuring the strength and reliability of the Lower Structure of the Flat Car Frame,

knowing the size of the camber of the Lower Structure of the Flat Car Frame, and measuring the mechanical quantity of the Lower Structure of the Flat Car Frame.

2) Purpose and Purpose

The purpose of this standard is to test the strength of the structure and measure the camber of the Railway Flat Car Structure. While the goal is to find out the size of the camber and the strength of the Railway Flat Car Structure against the load received during its operation.

3) Scope

The scope of this standard is to test the Camber of the Railway Flat Car Structure as well as to measure the Camber and Mechanical Quantity of the Railway Flat Car Structure.

4) Normative Acuan

The main references to be used and adopted are IUC standards, SEN standards, IEC standards and National Regulations issued by the Ministry of Transportation.

5) Terms and Definitions

The terms that appear and are used in this standard are terms commonly used in railways that refer to regulations from the Ministry of Transportation, namely: Trains, Carriages, Lower Frame Structures of Railway Flat Carriages, Camber, Loading and Measurement.

6) Structure Type

The type of structure in question is the Railway Flat Car Structure

7) Structural Materials

The material or materials used are steel materials that are prevalent and special for railway structures.

8) Test Method

The test method follows an experimental test procedure by applying a certain load to the Lower Frame Structure of the Railway Carriage, which is in the form of a series of loads such as:

- Loading with vertical loads
- Loading with compression load
- Loading with jacking loads
- Loading With Twist Load
- Camber Measurement

9) Acceptance/ Test Pass Requirements

The condition for Passing the Test or Acceptance is that all loading and measurement results meet the main requirement, namely that the structure of the flat car's lower frame must withstand the maximum load given, namely the maximum structural stress does not exceed 75% of the yield point of the steel material used (adjusted to the Regulation of the Minister of Transportation). Meanwhile, the camber does not exceed (1/2000) of the length of the car body structure when it is empty without load.

CONCLUSION

The mechanical strength of the structure and the camber value can be ascertained through the application of testing methods and stages which include a series of strength tests against vertical loads arising due to the presence of loads, compression loads due to acceleration and deceleration, jacking loads due to repair reasons, twist loads due to twisting loads, and the results of measuring the camber value. The method and stages of structural testing and measurement of the camber of the lower frame of the railway will be beneficial for manufacturers, regulators, operators and other stakeholders in the field of national railways, especially as a reference for both the design, manufacturing and operation of railways. The design concept, which contains standards on the methods and stages of structural testing steps and camber measurement of railway undercarriage camber, can be used as a starting material to prepare a national standard (SNI) in the manufacture of undercarriage undercarriage structures.

REFERENCES

[1] Belinterlogistic International Transportation, Types of Railways and Container,2009.
[2] Reliability, Availability, Maintainability, Safety (RAMS) and Life Cycle Costs (LCC), Committee on Technical Cooperation in the

Development of the Rail Transport System / 11th July 2016.
[3] Santarremigia FE, Molero GD, Poveda-Reyes S, Aguilar-Herrando J. Railway safety by designing the layout of inland terminals with dangerous goods connected with the rail transport system. Safety Science. 2018 Mar 14.
[4] Amtrak Mechanical Department Bureau of Rolling Stock Engineering, Specification For Trainset, Priia Specification No. 305-007 Amtrak Specification No. 979, August 2, 2011.
[5] Testing Procedure of Vertical Load Test, Doc.Nr. 005/P.MK/G.028/ 2010, PT. INKA Madiun, 2010.
[6] Testing Procedure of Compression Load Test, Doc.Nr. 003/P.MK/ G.028/ 2010, PT. INKA Madiun, 2010.
[7] Peraturan Menteri Perhubungan RI No. PM.17 tahun 2011 tentang Standar, Tata Cara Pengujian dan Sertifikasi Kelaikan Gerbong, 2011.
[8] Peraturan Menteri Perhubungan RI No. KM.43 tahun 2010 tentang Standar Spesifikasi Teknik Gerbong, 2010.
[9] Sherri L. Jackson, Research Methods A Modular Approach, Wadsworth/ Cengage Learning, Belmount, USA, 2010.
[10] Suharsimi Arikunto, Prosedur Penelitian, Suatu Pendekatan Praktek, Rineka Cipta, Jakarta, 2014.
[11] Jong-Duk Chung and Jang-Sik Pyun, A Study on Analysis Method Considering Camber for the Carbody Deflection of the Urban Transit Vehicles, Advanced Materials Research Vol. 871 (2014) pp 323-329 Online : 2013-12-19 © (2014) Trans Tech Publications, Switzerland, 2014.
[12] AAR M-201, Casting Steel Specification, AAR Manual of Standard and Recommended Practices Casting Details, October 2010.
[13] David Wennberg, A Light Weight Car Body for High-Speed Trains, Literature study, Centre for ECO2 Vehicle Design, Department of Aeronautical and Vehicle Engineering - KTH, 2009.
[14] European Structural Steel Standard EN 10025 : 2004.
[15] Zhang Z, Dhanasekar M. Dynamics of railway wagons subjected to braking/traction torque. Vehicle System Dynamics. 2009 Mar 1 ; 47(3) :285-307.