Relevant publications

1. Anghel Cernescu, Ion Dumitru, Lorand Kun, *Multiaxial fatigue damage prediction in a proportional loading cycle*, The Romanian Journal of Technical Sciences – Applied Mechanics, vol. 65(1), pp. 68-83, 2020;

2. Anghel Cernescu, N. Faur, C.M. Bortun, M. Hluscu, *A methodology for fracture strength evaluation of complete denture*, Engineering Failure Analysis, 18(5): 1253-1261, 2011;

3. Anghel Cernescu, N. Faur, C.M. Bortun, C. Nes, *Fatigue crack growth rate in acrylic resins under variable amplitude loading*, Theoretical and Applied Fracture Mechanics, 56(1): 58-61, 2011;

4. Anghel Cernescu, J. Romanoff, *Bending deflection of sandwich beams considering local effect of concentrated force*, Composite Structures, 134: 169-175, 2015;

5. Anghel Cernescu, J. Romanoff, H. Remes, N. Faur, J. Jelovica, *Equivalent mechanical properties for cylindrical cell honeycomb core structure*, Composite Structures, 108(1): 866-875, 2014;

6. Anghel Cernescu, I. Dumitru, N. Faur, N. Branzei, R. Bogdan, *The analysis of a damaged component from the connection system of the wagons*, Engineering Failure Analysis, 29: 93-107, 2013;

7. Anghel Cernescu, H. Remes, P. Lehto, J. Romanoff, *Fatigue crack growth rate in laser-welded web core sandwich panels – fatigue crack propagation in welded base metal*, 11th International Fatigue Congress, PTS 1 and 2, Advanced Materials Research, 891-892: 1212-1216, 2014;

8. Anghel Cernescu, *The influence of crack tip shielding on fatigue crack propagation*, Frattura Ed Integrita Strutturale, 41: 307-313, 2017;

9. Anghel Cernescu, *The role of microstructure on fatigue crack propagation*, Book chapter in *Recent Trends in Fatigue Design*, Nova Science Publishers, 2015;

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Review

A methodology for fracture strength evaluation of complete denture

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ABSTRACT

Objective: This paper presents a methodology for evaluating the mechanical strength and structural integrity of complete denture based on a thorough study on the mechanical properties of dental material and numerical FEM analysis.
Methods: A light curing composite resin, Eclipse (Dentsply International Inc.,– DeguDent GmbH, Hanau, Germany) was tested to evaluate the mechanical properties. According to standards recommendations were performed tensile and bending tests, fracture mechanics and fatigue crack growth rate tests. Using ABAQUS software, was performed a complex FEM analysis on a denture model obtained by 3D scanning and reverse engineering techniques, which may reveal if the applied load can initiate a crack or not. For if a crack is initiated, based on the methodology presented in this study, is analyzed the effect it has on complete denture.
Results: For a pressure load of 1.5 MPa, applied on palatal cusps of the upper teeth, we identified the stress concentrations areas, the values of maximum principal stress and strain, and were observed that a crack is initiated. Based on XFEM analysis were evaluated the stress intensity factors at the crack tip and was determined an equivalent stress intensity factor, $K_I^{eq} = 7.42$ MPa $\sqrt{\text{mm}}$. The value of K_I^{eq} is lower than the threshold stress intensity factor range, ΔKth (resulted from experimental tests), which means that the crack initiated is a stationary crack. Based on results, was calculated a risk factor, which give the fracture probability of the complete denture.

1. Introduction

The loss of teeth impairs patients' appearance, masticatory ability and speech, thus upsetting the quality of their social and personal life [1]. To restore these functions, removable and complete dentures are often used. The selection of materials for the construction of dentures is crucial because this directly relates to the performance and life span of the appliance during service in the oral cavity. Generally, the complete dentures are made of acrylic composite resins, as basis, and artificial teeth. Acrylic composite resins consist of three primary ingredients: an organic resin matrix, inorganic filler particles and a coupling agent [2,5]. Due, to the brittle fracture behavior and sometimes the processing technology of these materials, there can be obtained complete dentures with small defects which can initiate cracks and resulting in failure of total denture before the expected life time. Among the prevalent fracture types, 29% was a mid-line fracture, in which 68% were observed in maxillary complete dentures and 28% in mandibular complete dentures [4]. The longevity of the maxillary complete dentures for patients with occlusion against mandibular natural dentitions is about 21 months, whereas the average denture life time for those with occlusion against artificial mandibular teeth is of about 10 years [6]. Dorner and all pointed out that the

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Fatigue crack growth rate in laser-welded web core sandwich panels - fatigue crack propagation in welded base metal

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Abstract. The all-metal web-core sandwich structure consists of two face plates stiffened by one-directional system of web plates. These web core sandwich structures are used in many structural applications such as ship hulls, offshore platforms, bridge decks, and industrial platforms. However, the stress variation caused by the service loadings can be a determinant factor for crack initiation and growth until early failure of the entire structure. This paper presents an experimental study on fatigue crack growth rate in base material from a face plate after rolling and welding. The study is focused on the analysis of the stress ratio and crack closure effect on the fatigue crack growth rate in two directions. There is a significant stress ratio effect on fatigue crack growth rate, much more pronounced in the case of crack propagation in the longitudinal direction than in the transverse propagation. For all tests, the crack closure effect is more pronounced at low stress intensity factor range (in the threshold domain).

1. Introduction

The laser-welded web-core structure is an all-metal sandwich which consists of the steel panels fabricated as two face plates stiffened by one-directional system of web plates. These web core sandwich structures are used in many structural applications such as ship hulls, offshore platforms, bridge decks, and industrial platforms. The stresses that such a structure may encounter during its service life are due to the weight of the structure, payloads that it carries, fatigue loads by hull-girder bending, impact and thermal loads. These can cause a detrimental effect resulting in cracks initiation. The cracks then grow and extend into other locations of the structure due to the application of various service loads, leading to an early failure of the entire structure. Kujala et al [1] have shown that in the case of fatigue shear loading of a sample cut from a corrugated core sandwich panel, the cracks initiate on the heat affected zone, develop first along the weld and then turn 45° due to the shear and propagate to the next weld. Based on the full/scale model tests of corrugated core sandwich panels, Kozak [2] have shown five cracking models that can occur during the fatigue loading, fig. 1. These cracking models are depending on the type of structure geometry, applied loading and support mode. Also, Frank et al [3] investigated the fatigue strength of laser-welded web core sandwich panels under bending loading, based on the J-integral approach applied to panel laser stake-welded T-joints. In their analysis, the panel fatigue life was considered as the number of load cycles until the final separation of the face and web plates at one of the panel joints. In all this reported studies regarding the fatigue damage of sandwich panels, the fatigue crack growth rate of the cracks initiated is not taken into account. Nor is the influence of the stress ratio.
In this sense, within this paper is developed a study on the fatigue crack growth in the face plates of a web core sandwich panel. In the first part of this study, the fatigue crack growth rate analysis was made taking into account the *stress ratio and crack closure effect*. Also, the analysis was performed on the base material, following that in the second part of the study to be analyzed the fatigue crack growth rate in welded metal and HAZ (Heat Affected Zone).

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Bending deflection of sandwich beams considering local effect of concentrated force

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ABSTRACT

The sandwich constructions are widely used in various industrial applications due to their ability to provide high bending stiffness coupled with light weight. In general, the sandwich structures are designed as panels that must carry bending loads. The three-point bending test is one of the most common material testing procedures for investigating the properties and behavior of materials with structural applications. In this sense, the bending deflection is one of the properties investigated by bending tests and is associated with the stiffness of the analyzed material.

Considering this, within this paper is proposed a correction to first and Reddy's third order shear deformation theory to determine the bending deflection of sandwich beams. The method is based on the Timoshenko's theory for highlighting the local effect given by the applied load, adapted for sandwich structures. Also, this method approach the bending deflection maintaining compact the sandwich beam, is easy to apply and accurately estimate the vertical displacements along the cross-section. Two sandwich configurations were analyzed in the paper. The results showed on the one hand, the capability of the proposed relations to accurately estimate the vertical displacements of different points on the cross section and on the other hand the core flexibility effect on the bending behavior of the analyzed sandwich beams.

1. Introduction

The sandwich structures have been shown to be the most effective elements for strength and stiffening, and this is shown by the numerous industrial applications and respective designing configurations. Besides the strength, stiffness and strain energy absorption capacity are other basic characteristics of sandwich structures.

In general the sandwich structures are designed as panels that carry bending loads. The bending stiffness is characterized by the slope of the variation curve between the applied force and the vertical displacement of the point of application of force. This vertical displacement is often associated with the vertical deflection of the sandwich structure. In this regard, based on the Timoshenko beam theory, Allen [1] proposed the following relation for the total deflection, δ, at the mid-section of a sandwich beam loaded in 3-point bending:

$$\delta = \frac{Fl^3}{48 \cdot EI_{eq}} + \frac{Fl}{4 \cdot GA_{eq}} \tag{1}$$

where EI_{eq} is the equivalent bending stiffness of the sandwich beam and GA_{eq} is the equivalent shear stiffness of the sandwich beam and l is the span length.

Eq. (1) was generally accepted and assumes that in the loading plane the vertical deflection of the neutral axis is the same as the vertical displacement of the point of application of force. In reality there are very few cases in which this condition is valid. In the case of bending of sandwich beams with flexible cores (e.g. foam, cork) and thin faces, the variation curve of the applied force and vertical deflection can be easily affected by the occurrence of some local effects such as indentation or core damage.

Rubino et al. [2] have conducted an experimental study on three-point bending of *Y*-frame and corrugated core sandwich beams. They showed that the indentation of the core is the main contributor to the displacement, δ, of the loading point and proposed an analytical upper bound model for the indentation response of the sandwich beams. The energy absorption capacity of empty and aluminum foam-filled beams with corrugated cores have been experimentally and analytically studied by Yan et al. [3]. Failure mechanism maps for three-point bending were constructed for both empty and filled sandwich beams and the bending stiffness, initial failure load and peak load were predicted by theoretical analysis. The results have shown that filling of

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Equivalent mechanical properties for cylindrical cell honeycomb core structure

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ABSTRACT

Structural members made up of two stiff, strong skins separated by a lightweight core are known as sandwich panels. The separation of the skins by the core increases the moment of inertia of the panel with little increase in weight, producing an efficient structure against in-plane and out-of-plane loadings. In general, the mechanical behavior of cellular structures is given by the effective elastic modules, which are also dependent on the structure topology and different geometric parameters. This paper presents analytical equations for equivalent stiffness properties of a cylindrical cell honeycomb core. The cylindrical cells are obtained by connecting bended plate strips using adhesion or laser-welding. The stiffness properties and effective elastic modules for in-plane and out-of-plane compression and shear loadings are derived using an energy based approach. The analytical models are validated by 3D finite element method based on solid elements. The obtained mechanical properties are used to assess the stress and strain state of a sandwich beam in three-point bending. The present investigation shows that the analytical equations can predict the stiffness coefficients and respectively the effective elastic modules with very good accuracy.

1. Introduction

Sandwich structures have excellent mechanical properties, such as ratio between weight, stiffness and weight and strength. Therefore, the topic has been studied extensively in scientific research. This paper presents a sandwich structure with cylindrical cell honeycomb core. Typically, the sandwich panels are loaded by spatially varying transverse loads, and consequently the core of the panel must possess adequate compressive and shear stiffness and strength. The properties of the core are sensitive to both material choice and topology. There has been a significant activity in creation, manufacturing and testing of new topologies, starting with foam and honeycomb cores and continuing with structures as: metallic truss cores and all-metal sandwich panels.

Cellular materials offer low densities and are efficient in absorbing energy from external loading. In the past decade, major advances were made in the design of cellular materials with periodic topologies by exploiting minimum weight design, novel material fabrication processes, quasi-static and dynamic experiments, and large-scale simulations.

Honeycombs usually comprise hexagonal or square cells, with the prismatic direction normal to the plane of face plates of the sandwich panel. Hexagonal honeycombs are routinely employed as the cores for lightweight sandwich panels and as energy absorbers; they are typically manufactured from aluminum alloys and have a relative density $\bar{\rho}$ (ratio of the density of the honeycomb treated as a homogeneous continuum to the density of the solid) of less than 3%. Experiments and simple analyzes have shown that their out-of-plane elastic properties scale linearly with their relative density $\bar{\rho}$, [1]. In out-of-plane crushing, these honeycombs exhibit a stress peak followed by large stress oscillations associated with the formation of a succession of plastic folds within each cell. The out-of-plane shear strength is governed by cell wall buckling as discussed by Zhang and Ashby, [2]. Once the wrinkles have formed, the shear stress drops and subsequently remains approximately constant until failure occurs by the fracture of the cell walls. Square honeycomb cores having a high relative density ($\bar{\rho} > 0.05$) are preferable over hexagonal honeycombs for high loadings such as blast and shock loads because of their high out-of-plane crushing resistance; shear resistance and in-plane stretching strength, [3]. Circular cell honeycombs have also been studied analytically and experimentally by J. Chung and Waas, [4–7], for uniaxial and biaxial compressive in-plane loads. They observed an orthotropic behavior of these structures and also presented analytical solutions for determining the in-plane elastic properties. It

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Fatigue crack growth rate in acrylic resins under variable amplitude loading

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ABSTRACT

Dental materials made of resin composite offer many advantages over those made of amalgam. They are easy to use, durable and esthetically pleasing. These materials in the oral cavity are subject to different environments and fatigue loadings. The objective of this manuscript was to evaluate the fatigue behavior of acrylic resins under variable amplitude loading conditions. Two types of acrylic resin were used for this analysis (heat-polymerizing resins – Meliodent and Royaldent). These materials are usually used as acrylic bases for total dentures and have been prepared in accordance to the manufacturer's recommendations. For fatigue fracture analysis, were performed crack propagation tests on CT-type specimens, according to ASTM E647 standard. The tests were carried out on a servo-hydraulic testing machine, for cyclic loadings with variable amplitude and different stress ratio, *R*. The compliance method was used for fatigue crack length measurements.

The characteristics of fatigue crack propagation were expressed as the correlation between the fatigue crack growth rate (da/dN) and crack length (a) and the stress ratio (R). Based on experimental results, was analyzed the notch and loading effect on fatigue crack growth rate in acrylic resins.

Conclusions: One of the conclusions of this study is that the deformed area near the notch has a significant effect on fatigue crack propagation. As we increase the stress ratio of the cyclic spectrum, the loading effect is still smaller and fatigue fracture is controlled by the crack length. Acrylic resins have a brittle fracture behavior and crack length plays an important role in fatigue crack growth.

1. Introduction

Acrylic based resins consist of polymeric materials based on polymethylmethacrylate. These dental materials are the result of a free radical polymerization reaction. They can be classified as chemical, heat or light activated depending on the factor that initiates the reaction.

Acrylic based resins are frequently used in daily dental practice, as they are able to provide the essential properties and necessary characteristics to be used in diverse functions. Most common use of the materials includes denture bases and denture liners, orthodontic appliances and temporary crowns.

Denture bases are composed of pre-polymerized polymethylmethacrylate (PMMA) or polyethylmethacrylate (PEMA) powder particles along with a peroxide initiator and a pigment, which are mixed with methacrylate monomers (methylmethacrylate) and cross-linking agents such as ethyleneglycoldimethacrylate, trimethylolpropane or trimethacrylate [1].

Denture liners are used to improve the fit of denture bases, thus re-establishing the retention, support and stability of removable prostheses [2]. Orthodontic appliances are used for space maintenance, thumb deterrent, tipping teeth, overbite reduction, block movements and retention. PMMA is the material most commonly used for manufacturing the polymeric part of these orthodontic appliances [3]. Temporary crowns are used during the interval between tooth preparation and placement of the definitive crown.

An important issue regarding the clinical application of the acrylic based resins is their biodegradation. It can be defined as the changes on their chemical, physical and mechanical properties due to the oral environment conditions.

In the oral environment, long-term deterioration in dental restoratives can be induced by fatigue, which is caused by relatively weak repetitive loads such as ordinary chewing force. A continuous application of mechanical and environmental loads leads to progressive degradation and crack initiation and growth, resulting in failure of the resins. This process is further assisted by pre-existing voids introduced during the material processing and residual stresses [4]. Therefore, investigation of the characteristics of fatigue crack propagation in composites is important in the evaluation of fatigue resistance. Dynamic fatigue crack propagation tests for acrylic resins were previously established using compact-tension specimens with double-cantilever shape [5–7]. The present study investigated the notch effect, stress ratio effect and crack length on the fatigue crack growth rate using the above tests.

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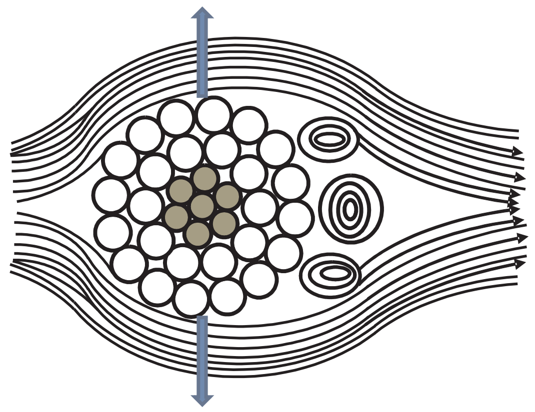

EDITURA ACADEMIEI ROMÂNE

MULTIAXIAL FATIGUE DAMAGE PREDICTION IN A PROPORTIONAL LOADING CYCLE

ANGHEL CERNESCU , ION DUMITRU, LORAND KUN

Abstract. Mechanical components of in-service machines are frequently subjected to multiaxial cyclic loading, which can result in failure due to the fatigue damage. In general, the multiaxial fatigue life can be predicted based on the stress/strain states variation and using a damage criterion. In this paper, fatigue damage given by a proportional tension-torsion loading cycle is predicted based on proposed methodology. Fatigue damage prediction is made using Findley's criterion on the Mohr's circles of the stress states. The results showed a good capability of the Findley criterion to predict both the critical plane and durability on the analyzed material.

Key words: Multiaxial fatigue, Proportional tension-torsion, Mohr's circle, Findley's criterion, Multiaxial fatigue damage.

1. INTRODUCTION

Fatigue phenomenon is the progressive and localized structural damage which occurs when a material is subject to cyclic loading. The process starts with dislocation movements which form persistent slip bands leading to initiation of cracks that propagates until final failure. Also, this process is carried out over time and defines the durability of a material, respectively component. Depending on the durability domain in which the material is loaded, the life time prediction is quantified by the number of cycles to initiate a crack at a critical point (low-cycle fatigue), or the number of cycles recorded until the final failure, given by the initiation and propagation of a crack from a critical point (high-cycle fatigue or very high cycle fatigue). Basically, the fatigue life prediction of a material represents the damage degree at the end of a loading cycle, which is then cumulated by repeating the loading cycle until the actual failure. Therefore, a major problem in fatigue life prediction is the estimation of the damage caused by a loading cycle. In general, the loading cycle is defined as all the values recorded by the load (forces, moments, pressures, temperatures, etc.), starting from a mean value, recording a maximum, then a minimum and returning to the mean value. The applied cyclic loading determines a stress respectively strain state in material

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The influence of crack tip shielding on fatigue crack propagation

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ABSTRACT. The fatigue crack propagation is one of the major problems and of the real concern in the evaluation of the structural integrity of components. This is due to the fact that once a fatigue crack has been detected it is also known its effect on the component; respectively it will cause failure at one time. In this situation, the problem is focused on determining the character of propagation of the crack so that it can be estimated and respectively delayed as possible the failure moment. The fatigue crack propagation character is determined by the stress state at the crack tip and the behavior of the material in which the crack is propagates. One of the phenomena with great influence on the fatigue crack propagation character is the crack tip stress shielding phenomena. In this paper the overloading effect is explained in terms of crack tip shielding mechanisms that guide the fatigue crack growth in plastic zone. The results indicate a change of fatigue crack propagation character once its tip enters into a plastic zone.

KEYWORDS. Fatigue crack growth rate; Crack tip shielding; Crack closure; Overloading cycle; Plastic zone.

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INTRODUCTION

One of the current approaches of fatigue damage predictions is based on the damage tolerance concept. This concept starts from the premise that each component has a potential defect and the fatigue life is based on the number of cycles required for an initial crack to grow to the critical value. Using an appropriate fatigue crack growth equation, the initial fatigue crack is propagated through iterative calculations that take into account the loading spectrum, material properties and component geometry. One of the elements that confer the degree of accuracy of fatigue crack growth predictions is represented by the crack closure phenomenon. According to the review made by M. N. James, [1], on the crack closure, the first study that has highlighted such a phenomenon was presented by Christensen in 1963, [2]. Performing fatigue crack growth tests on center-cracked specimens of 2024-T3 aluminum alloy it was observed an increase in fatigue life occurred in the presence of trapped oxide particles between the fracture surfaces.
However, of reference are the Elber's studies from 1970 and 1971, [3-4]. Based on residual stress distribution and resultant forces analysis in center-cracked plate specimen under zero-to-tension loading, Elber showed that the crack is fully open only for a part of the loading cycle. This being attributed to the field of plastic deformations in the wake of

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Chapter 7

THE ROLE OF MICROSTRUCTURE ON FATIGUE CRACK PROPAGATION

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ABSTRACT

The fatigue crack growth rate is the essential element of the evaluation concept based on damage tolerance and this made that the fatigue crack propagation to be the subject of many studies. The microstructure has fundamental influences on fatigue crack propagation. In this paper it is conducted a review based on experimental observations which aims to highlight the role of microstructure on the fatigue crack growth rate. It was observed that the presence of a hard constituent in ferrite matrix may have significant effects on the fatigue crack growth rate. Both morphology of hard constituent and volume fraction can determine the changing of propagation constants and introduces the retardation effects of fatigue crack. On the other hand the crystallographic characteristics and orientation of grain boundaries also influence the fatigue crack propagation. The twist and tilt angles of the slip systems from two adjacent grains may lead to retardation effects on crack

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The analysis of a damaged component from the connection system of the wagons

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ABSTRACT

The operation of passenger trains in different continents is still differentiated by different wagon connections systems. The predominant wagon connection in North America and Australia is the autocoupler system. The system of draw hooks and buffers is now rare. In Europe, draw hook and buffer systems are still in wide use. In particular, the majority of passenger trains in Romania have wagons connected by draw hook and buffer systems. This paper presents an unusual situation for analysis of a damaged component of draw hook system and where has been lost the basic information about the causes of failure. Due to the lack of information, the analysis has a high degree of assumptions, being based on failure scenarios. The broken component is a link plate made of forged steel. After an initial examination of the fracture surface, was observed the existence of a structural defect in the material from which was initiated a fatigue crack. The analysis involves an experimental evaluation of the mechanical properties of the failed component material, followed by the modeling of the behavior of connection system according to the position where is mounted on the train. Based on the mode of fatigue crack propagation, correlated with the loading level of the connection system, different scenarios have been made about the time of propagation. Because important information about the failure causes was lost, the analysis was performed taking into account almost all factors that could influence the fatigue crack propagation.

This analysis came in completing the expertise done by specialists in Traffic Safety on the Railways.

1. Introduction

Railways wagons are some of the most important means for passengers and cargo transporting. The couplings bind the railway wagons together to form an entity named the train. In the longitudinal movement of the trains, the couplings have an important role in connecting adjacent wagons and the locomotive, while allowing the transmission of the locomotive traction force on the axial direction. Besides the above condition the couplings must allow relative movements between wagons both in the vertical direction, produced by the each wagon suspensions and horizontally determined by the raceway. In addition, in some cases these must allow a rotation movement around of its own axis. Another requirement imposed to the couplings lies in its ability to cushion the shocks received by the wagons. Operational safety of the wagon couplings depends primarily on their ability to resist at the tensile and compression dynamic forces generated by the propulsion or braking of the train. The increase in tonnage and velocity simultaneously with changing the forces that acts on the couplings lead to a reduction of durability of wagon couplings due to the failure of some components [1–8]. On the other hand, the high

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