MINISTRY OF TRANSPORTS AND INFRASTRUCTURE
ROMANIAN RAILWAY AUTHORITY – AFER
ROMANIAN RAILWAY INVESTIGATING BODY

INVESTIGATING REPORT

Of the railway incident occurred on March 13, 2008

Final edition
May 18, 2009

The Romanian Railway Investigating Body performed an investigation action according to the provisions of Law no. 55/2006 on the railway safety as regards the serious railway event that took place on March 13, 2008 to Zavideni railway station taking into consideration that this case is part of a series of relevant incidents for the entire railway system.

By the investigation action performed were collected and analyzed the information related to the railway incident occurrence, were established the conditions and the causes were determined.

The action of the Romanian Railway Investigating Body didn't have as purpose to establish the guilt or the responsibility.

The Romanian Railway Investigating Body considers that is necessary to be taken into consideration a series of corrective measures in order to improve the railway safety and to prevent the railway accidents and incidents and therefore has issued in the present report a series of safety recommendations.

Bucharest, May 18, 2009

DIRECTOR
Dragos FLOROIU

CONTENT

A. INTRODUCTION

1. The Romanian Railway Investigating Body started the investigation for the railway incident occurred on March 13, 2008 at the hour 03:00 on the Railway County Craiova area to Zavideni railway station by the breaking of the axle journal from wheel no.5 from the wagon no.315354943062 (the sixth from the locomotive), loaded with iron rust, from the freight train no.41651 belonging to the Romanian Railway Freight Company „CFR Marfa" SA, as it is a part of a series of similar railway events relevant for the railway system that occurred in the circulation of the freight trains (in the period 2004-2005 a number of five similar railway events took place).

2. The investigating action does not have as purpose to establish the guilt or the responsibility, this action being performed in parallel with other investigating actions.

3. The occurred facts were qualified as railway incident according to the Law no.55/2006 on the railway safety with relevance for the railway system, reason for which the Romanian Railway Investigating Body director took the decision to perform an investigating action.

4. By the decision no.6 from March 17, 2008 of the Romanian Railway Investigating Body director the investigating commission was appointed being composed of:

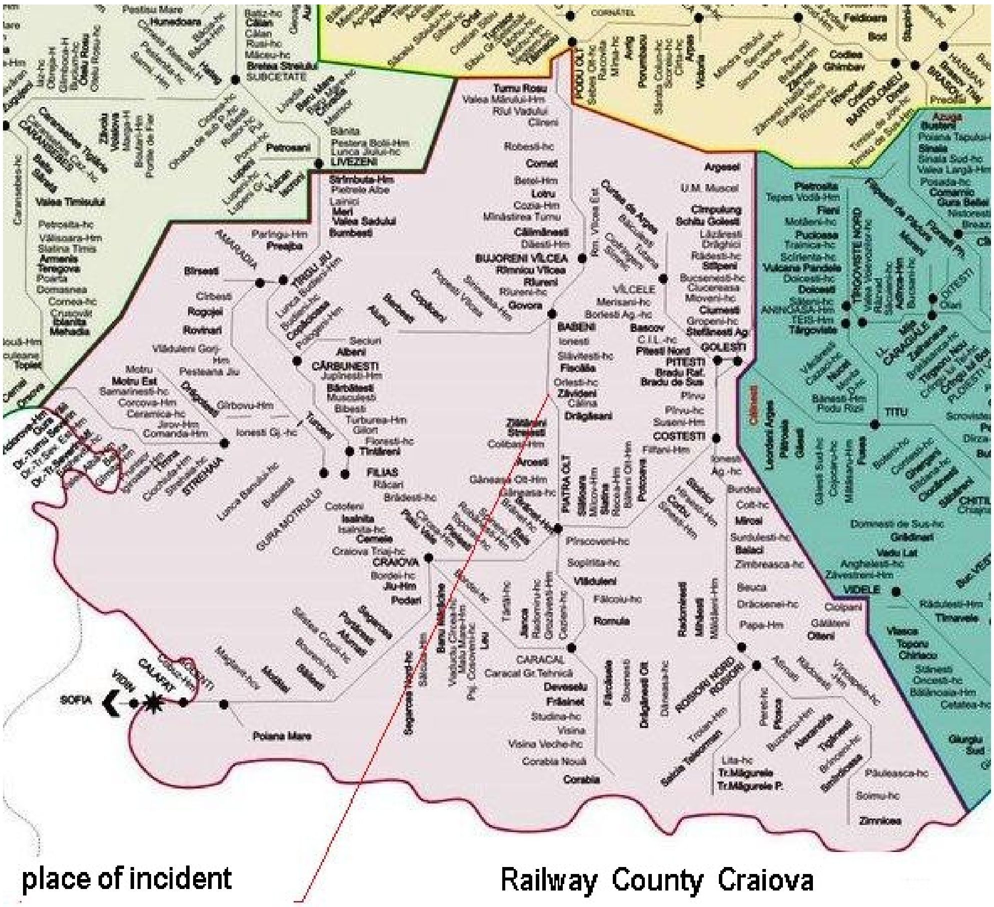
Olaru Mihai	- investigator in charge
Ciobanu Eugeniu	- investigator
Zamfirache Marian	- investigator
Nicolescu Mircea	- investigator

5. In order to determine the causes that led to the breaking of the journal axle, Romanian Railway Investigating Body requested the performance of a test report within the Laboratory Department of AFER. Following this study (Annex 1) resulted a series of parameters and conclusions that didn't allow to identify the causes of the journal axle breaking. As result of obtaining insufficient results, the investigating commission requested the extension of expertises asking „ Politehnica" University of Bucharest - Centre for Research and Eco-Metallurgical Expertise – ECOMET that following the performed tests has drawn up a technical report presented in annex no.2.

B. THE RAILWAY INCIDENT RESUME

B.1. Short description of the railway incident

On March 13, 2008, the freight train no. 41651, belonging to the railway undertaking Romanian Railway Freight Company „ CFR Marfa” SA, composed of 25 wagons, hauled by the electric-diesel locomotive DA 1241 was dispatched from Piatra Olt railway station at hour 01:32. The train circulated until Dragasani railway station, where having command to enter on the first direct track was visually inspected by the movement inspector that noticed sparks to the sixth wagon from the locomotive to the second bogie in the running way.



As a result, the movement inspector informed the engine driver by radio station in order to stop the train. After stopping, the driver’s assistant went to the wagon no.31535494306-2 (the sixth from the locomotive), performed a visual examination of the wagon and verified the tightening and the release of the brakes without finding any irregularities.

After the examination, the train was put into motion, the engine driver continuing to watch the wagons by the retrospection mirror. After passing P.O. Călina (area with inclined track), noticing sparks to the wagons from the train composition and also when switching on“0” the control switch group, the trains speed didn’t increase, the engine driver being informed by the movement inspector of Zavideni railway station through the radio station took measures in order to stop it. At the hour 03:00 the train was stopped to the first direct line of Zavideni railway station.

After the train stopped the driver’s assistant performed the inspection and together with the movement inspector of Zavideni railway station noticed to the wagon no.31535494306-2 (the sixth from the locomotive) that the axle journal no. 5 was broken.

It was no injured persons or damages to the track, installations or to the rolling stock except the wagon no. 31535494306-2.

Zavideni railway station is located on the running section Piatra Olt – Ramnicu Valcea, belonging to CNCF "CFR" SA Railway County of Craiova.

B.2. Direct cause

The direct cause of the railway event occurrence is the breaking of the wheel set no. 3836632 from the wagon no. 31535494306-2 in the area of the stress relief clearing between the axle journal and shutter as result of the decrease of the material fatigue strength against the development of micro cracks in the areas with high density of the networks with manganese sulphide.

B.3. Underlying causes

- Exceeding the allowed limit for the sulphur concentration (determined values of 0,05 – 0,06% in comparison of the maximum allowed limit 0,04%) which determined the appearance of a discontinuous networks of manganese sulphide inclusions with negative influence on the breaking properties to fatigue of the material.
- Exceeding the allowed limit for the copper concentration (values of 0,35 – 0,37 % in comparison with the maximum allowed limit 0,3%) the noticed inclusions lines can form breaking cracks and corrosion cracks of the material, with negative influence on fatigue resistance.

B.4. Root causes

The non-compliance with the minimum imposed conditions on the chemical characteristics of the axles axis established in the reference documents in force at the date of manufacturing (STAS 1947/1990 - Wagons with standard gauge. Axles. General technical conditions of quality and the UIC leaflet 811-1/1987 – Chemical composition, mechanical tests, Axles axis).

B.5. Safety recommendations

According to the provisions of the Law no.55/2006 in order to improve the railway safety and to prevent some similar railway accidents and incidents, the Romanian Railway Investigating Body structured a series of safety recommendations:

1. Withdrawal from circulation of all axles from the charge no.311561 produced by SC SMR SA Bals, from which the axle no.3836632 was a part, for the non-compliance of the conditions established by the UIC leaflet 811-1/87 - Chemical composition, mechanical tests, Axles axis and the rejection of the respective charge.
   SNTFM „ CFR Marfa" SA, other railway undertakings and also owners of wagons equipped with axles from the charge no.311561 will perform investigating actions and will comply with the present recommendation.

2. The performance of a control action by the railway undertakings that have technical departments of reception to the railway suppliers that are offering the working material in order to manufacture metallic elements used to parts and subassemblies from the mechanisms of the railway vehicles that are ensuring the railway safety (the running gear - wheels, axles, bearings and others, the draw and coupling gear - hooks, bars and others, respectively the buffing gear - buffers, springs) by which to identify the cases of non-observance of the own procedures of drawing the material. The conclusions of this control action and also the established measures will be included into a report that will be submitted to the Romanian Railway Authority – AFER the latest August, 2009.

3. On the occasion of the state inspections scheduled by the Romanian Railway Safety Authority it will be supervised the method of implementation of the quality system assurance to the railway suppliers

that are offering the working material in order to manufacture metallic elements used to parts and subassemblies from the mechanisms of the railway vehicles that are ensuring the railway safety (the running gear - wheels, axles, bearings and others, the draw and coupling gear - hooks, bars and others, respectively the buffing gear - buffers, springs).

4. The Romanian Railway Notified Body will assess the technical conditions that stood at the basis of granting the technical homologation certificate for the wheel set type AI manufactured by SC SMR Bals SA.

C. THE RAILWAY INCIDENT

C.1. The railway incident description

On March 13, 2008 the freight train no.41651 belonging to the railway undertaking SNTFM „ CFR Marfa" SA, composed of 25 wagons, 78 axles, 750 tons, 364 metres hauled by the electric-diesel locomotive DA 1241 was dispatched from Piatra Olt railway station at the hour 01:32.

The technical inspection when composing the freight train no.41651 was performed in Piatra Olt railway station by an examiner of SNTFM „ CFR Marfa" SA . On the occasion of technical inspection when composing the train and of the surveillance by visual inspection at dispatching the examiner didn't find any defects that can put in danger the traffic safety.

The train circulated until Dragasani railway station, without any comments.

The freight train no. 41651 that had command to pass on the first direct line from Dragasani railway station was visual inspected by the movement inspector , being on duty noticed sparks to the sixth wagon from the locomotive, to the second bogie in the running way. Following this, the movement inspector went to the traffic management office and informed through the radio station the engine driver in order to stop the train.

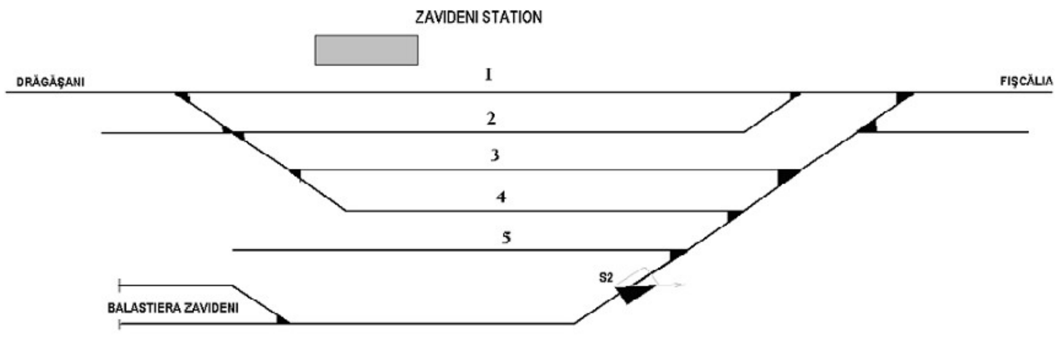
The engine driver of the train no.41651 when receiving the notification through the radio station from the movement inspector from Dragasani railway station took measures in order to stop the train and ordered to the driver's assistant to check the wagons 5 and 6 of the train composition.

After stopping the train in the area of the signal box no.2 of Dragasani railway station, the driver's assistant went to the wagon no. 31535494306-2 (the sixth from the locomotive) visually inspected the wagon, examined the tightening and the release of the brakes to the mentioned wagon without finding any irregularities.

After inspection, the train was put into motion, at hour 02:54 the engine driver continuing to watch the wagons by the retrospection mirror. The train covered approximately 285 metres, after which the engine driver noticed sparks to the wagons from the train composition and also the speed of the train that normally had to increase (taking into account that it was in down-grade and the control switch group was in position 0) was decreasing, so the engine driver took measures to stop it. At the hour 03:01 the train was stopped at the first direct line from Zavideni railway station.

The driver's assistant together with the movement inspector of Zavideni railway station examined the wagons from the train composition and to the sixth wagon no.31535494306-2 found that the axle journal no. 5 was broken and the axle box corresponding to the same journal was based on the part T.

Zavideni railway station was equipped with mechanical interlocking.



C.2. The legal framework of performing the investigation and the reasons that stood at the basis of issuing the decision of investigating the railway incident by NIB

According to the provisions of article 19 of the Law no.55/2006 was set up the Romanian Railway Investigating Body, a permanent body, independent within the Romanian Railway Authority – AFER that performs the investigation of serious railway accidents its objective being to improve the railway safety and to prevent the railway accidents. The Romanian Railway Investigating Body can investigate also those railway incidents and accidents that in conditions slightly different could have led to serious railway accidents, including technical defects of the structural subsystems or of the interoperability constituents of high speed or European conventional railway systems.

The railway incident occurred on March 13, 2008 at the hour 03:00 on the area of the Railway County of Craiova to Zavideni railway station by the breaking of the axle journal of wheel no.5 of the wagon no. 31535494306-2 (the sixth from the locomotive) loaded with iron rust, from the freight train no.41651 belonging to the Romanian Railway Freight Company „ CFR Marfa" SA, as it is a part of a series of similar railway events relevant for the whole railway system as in the period of 2004-2005 a number of five similar railway events took place as follows:

- The railway event occurred on July 15, 2004 on the activity area of Railway County of Bucharest, between the railway stations Videle- Zăvestreni due to the breaking of the axle journal in the connection area between the shutter and the wheel seat from the wheel set no.3835171, type II from the wagon no. 31537965905-7;
- The railway accident occurred on July 30, 2004 on the activity area of the Railway County of Iaşi to Cîmpulung Moldovenesc railway station due to the breaking of the axle journal in the connection area between the shutter and the wheel seat from the wheel set no.3835112, type AII from the wagon no. 31537965898-4;
- The railway event occurred on July 31, 2004 on the activity area of Railway County of Craiova, between the railway stations Zlătărei – Piatra Olt due to the breaking of the axle journal in the area of connection between the axle journal and the shutter, from the wheel set no. 3835154, type AII, from the wagon no.31537965885-1;
- The railway accident occurred on August 15, 2004 on the activity area of Railway County of Galati, to Gugesti railway station due to the breaking of the axle journal in the area of connection between the axle journal and the shutter, from the wheel set no. 3835162, type AII, from the wagon no.31537965883-6;
- The railway event occurred on January 20, 2005 on the activity area of Railway County of Constanta, to Basarabi railway station due to the breaking of the axle journal in the area of connection between the axle journal and the shutter, from the wheel set no. 3834230, type AII, from the wagon no.31535494033-2;

On the basis of article 19 paragraph (2) of the Law no.55/2006 on the railway safety the Romanian Railway Investigating Body decided to begin an investigation of the railway incident occurred on March 13, 2008 at the hour 03:00 on the activity area of the Railway County of Craiova, to Zavideni railway station by the breaking of the axle journal from the wheel no.5, from the axle no.3 of the wagon no. 315354943062, the sixth from the locomotive, loaded with iron rust, being in the composition of the freight train no.41651 belonging to SNTFM" CFR Marfa" SA.

C.3. The railway event circumstances

The personnel involved in the railway event occurrence and developing:

- The train preparer that performed the technical inspection when composing the freight train no. 41651 is the employee of SNTFM „ CFR Marfa" SA, The freight county of Craiova – Wagon Inspection of Piatra Olt;

- The engine driver and the driver's assistant that ensured the driving of the freight train no.41651 from the moment of composing the train in Piatra Olt railway station to Zavideni railway station are employees of SNTFM „ CFR Marfa" SA, The freight county of Craiova;
- The movement inspector of Dragasani railway station and the movement inspector of Zavideni railway station are employees of CNCF „CFR" SA, The Railway County of Craiova.

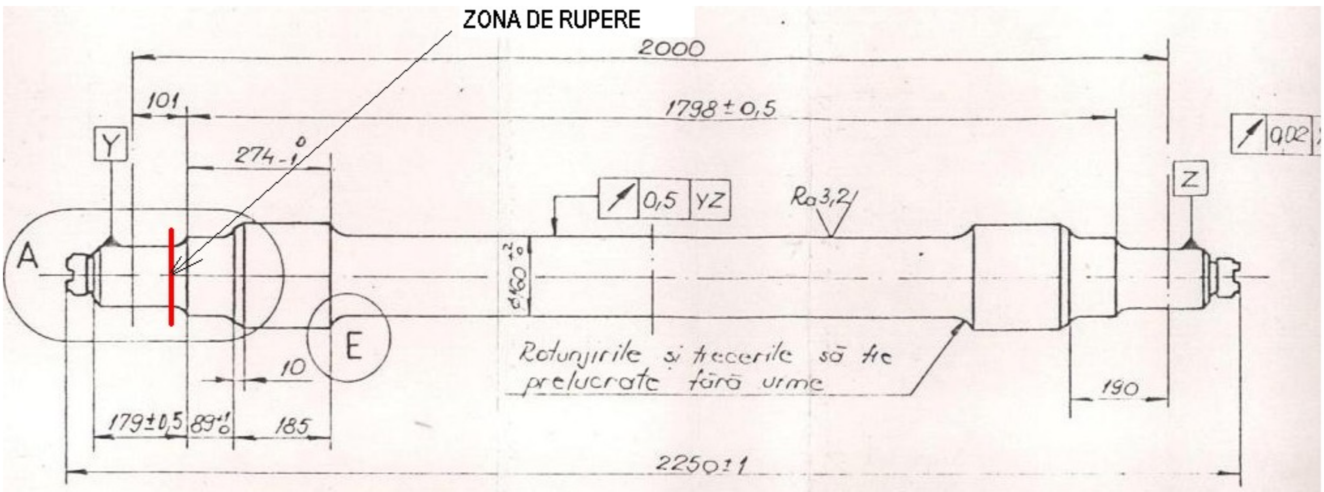
The railway infrastructure involved, respectively the running section Piatra Olt – Ramnicu Valcea is a simple non-electrified track managed by CNCF „ CFR" SA , The Railway County of Craiova.

The freight train no.41651 belonging to SNTFM „ CFR Marfa" SA composed of 25 wagons, 78 axles, 750 tons with a length of 364 metres, the real braked tonnage of 617 tons with a plus of 242 tons over necessary that was formed in Piatra Olt railway station.

The wagon no. 31535494306-2 is a open freight wagon self discharging type Eacs, for the freight transport in bulk and common goods , being equipped with bogies Y25Cs and automatic brake type KE-GP. The load capacity of the wagon is of 58 tons, the load on the axle being of 20 tons. The wagon is the property of SNTFM „ CFR Marfa" SA. The last repair of the wagon type RK (capital repair)- was performed in July 2004 by SC MEVA SA Drobeta Turnu- Severin that equipped the wagon with new wheel sets from SC SMR SA BALS . In august 2007 the inspection and the brake intermediate inspection of the wagon were performed to SC CFR IRV Constanta SA - IRV Petrosani Department. Also were performed repairs type RC – current repairs (on October 12, 2006 to IRV Sibiu Department and on August 6, 2007 to IRV Petrosani Department both belonging to the same economic agent).

When performing the wagon inspection on March 14, 2008 it was found that to the axle box from the extremity with the broken axle journal (the axle journal no.5) the quantity of grease was not sufficient, with normal aspect showing a correct operation of the roller bearings without any traces of irregular heating.

The axle having the registration number in the engine stock of CFR 3836632 (no.14) is a part of the charge 311561 manufactured by SC SMR SA Bals, axle type AI. The axle breaking occurred into an area located at a distance of 217-219 mm from the axle extremity, perpendicular on its longitudinal bar , on connecting the assembling part of the bearing WJ and the shutter.



In order to remove the consequences of the railway event it was used the hydraulic jack and a crane of 20 tf from the Engine Stock of Craiova.

C.4. The results of the railway incident

C.4.1. Victims and injured people

It weren't.

C.4.2. Material damages

- to the rolling stock, - the broken axle was replaced with the one supplied by SC SMR SA Bals, the axle being in its guarantee term.

- to tracks and installations - it weren't;
- to the environment - it weren't;
- the cost of the interventions means according to the estimate no.34 of March 18, 2008 of SC Railway Intervention SA is 8345,13 lei.

C.4.3. Traffic Interruption

The traffic was not interrupted as result of the railway incident occurrence.
On March 13, 2008 the following trains were delayed: train no.820 delayed three minutes, train no.1828 delayed three minutes and train no.93321 delayed 23 minutes.

C.5. External circumstances

On March 13, 2008 in the time period 01:00- 04:00 the visibility was very good, weak wind, the temperature was approximately 10º C, clear sky.

D. REGISTRATION OF THE INVESTIGATIONS

D.1. The resume of the testimonies of the involved railway personnel

The train preparer that performed the technical inspection to the composition of the freight train no.41651, being on duty on March 12 and 13, 2008 to the Wagons Inspection Point of Piatra Olt stated the following:

- he performed the technical inspection to the composition of the freight train no. 41651 and with this occasion it was performed also the complete braking test;
- to the wagon no. 31535494306-2 it wasn't found any defects and no intervention was done;
- with the occasion of supervising by visual inspection when dispatching, no defects were found to the wagons from the train composition;

On the occasion of the displacement to Zavideni railway station, after the railway incident occurrence, the examiner found that:

- the axle journal no.5 didn't indicate signs of superheating;
- the axle box from the broken axle journal was left fixed in the piece " T";

The engine driver of the locomotive DA 1241 that hauled the train no. 41651, stated the following:

- when passing to Dragasani railway station, the movement inspector informed him that he noticed sparks to the wagons no.5 or 6;
- he took measures in order to brake and to stop the train and he asked to the driver's assistant to verify the two wagons from the train composition;
- after the driver's assistant performed the inspection of the wagons he put the train into motion and he continued the route to Zavideni railway station, supervising the behaviour of the wagons from the train composition;
- when coming from PO Calina, at the entrance to Zavideni railway station, he noticed sparks in the retrospection mirror and also that the speed of the train was decreasing although the switch group was in position 0 and the train was descending with the automatic brake released;
- he stopped to Zavideni railway station in order to inspect the train;
- he asked the driver's assistant to verify the wagons from the train composition, the driver's assistant informing him that the wagon no.31535494306-2 has a broken axle journal.

The driver's assistant of the locomotive DA 1241 that hauled the train no.41651, stated the following:

- when passing to Dragasani railway station, the movement inspector informed that he noticed sparks to the wagons no.5 or 6;
- he performed the inspection of the sixth wagon from the train composition to Dragasani railway station in the presence of the points man from the cabin no.2 from the railway station and also performing to this wagon a braking test;
- he informed the engine driver that the train is ok and after putting into motion the train he surveyed its behaviour;
- when coming from PO Calina to Zavideni railway station, on the right side in the running way he noticed sparks to the wagons;
- when performing the inspection to the same wagon, he found that the axle journal was broken.

The movement inspector on duty when the railway event took place to CFR Dragasani railway station he stated the following:

- he surveyed by visual inspection the train no. 41651, that had order to pass on the first line;
- he noticed sparks to the sixth wagon no. 31535494306-2 , to the last bogie;
- he went to the dispatching office;
- he contacted by radio station , the engine driver of the train no.41651 in order to stop the train and to inspect the wagon;

- he received the confirmation that the train was stopped at the exit from Dragasani railway station in the area of the cabin no.2;
- The signalman from the cabin no.2 from Dragasani railway station transmitted him that the driver's assistant went to the mentioned wagon, inspected him and then the train continued its route;
- Also, the signalman from the cabin no.2 transmitted by the radio station the fact that after the train was put into motion and has increased the speed , he noticed again sparks to the wagons , at a bigger distance from the place where it was (the area of the cabin no. 2 of Dragasani railway station);
- He tried again to contact through the radio station the engine driver but he didn't succeed so that he informed the movement inspector of Zavideni railway station in order to stop and to inspect the train.

The movement inspector on duty when the railway incident took place to Zavideni railway station stated the following:

- he was informed by the movement inspector from CFR Dragasani railway station that to the train no. 41651 to the sixth wagon, appeared sparks on the right side in the running way;
- he requested through the radio station to the engine driver of the train no. 41651 to stop and he went together with the driver's assistant to the wagon no. 31535494306-2 where he found that the axle journal was broken to the third axle , on the right side of the running way.

The signalman on duty to the cabin no.2 of Dragasani railway station when the railway incident took place, he stated the following:

- the train no. 41651 stopped in the area of the cabin no. 2;
- the driver's assistant verified the wagon and then went to the locomotive, after the train being put into motion;
- after the train was put into motion, " at a big distance" he noticed sparks to the wagons from the train composition and reported this to the movement inspector from Dragasani railway station;

The movement inspector from Arcesti railway station and the movement inspector from Zlatarei railway station, the signalman from Zlatarei railway station and the barrier keeper from the level crossing km 236+158 (that was preceding the Dragasani railway station) didn't notice anything special at the visual inspection.

D.2. The safety management system

The activity of technical inspection of trains within SNTFM " CFR Marfa" is performed on the basis of the " Instructions concerning the technical inspection and the maintenance of the used wagons" no. 250 approved by the Order of the Minister of Transports, Constructions and Tourism no.1817 of October 26, 2005.

The control of own activities on the railway safety was performed on the date of the railway incident occurrence to the railway undertaking on the basis of the Order no.5 of February 13, 2007 of the General Director of SNTFM " CFR Marfa" SA.

Within the investigating process it was not found any lacks in the railway safety management system that was implemented to SNTFM " CFR Marfa" that could have been related to the railway incident.

D.3. Norms and regulations

The examination of the axle journals to the manufacturer in order to find cracks was performed by two proceedings, respectively:

- the ultrasonic control of the wheel sets on the basis of " The instructions for the ultrasonic control of the axles, mono block wheels and new tyres" issued by REFER RA in 1993;
- the control with magnetic powder according to the internal norms of SMR Bals.

The axle journal examination to this type of wagon within the maintenance works is done using a single non-destructive proceeding, respectively the ultrasonic control being performed until April 15, 2008 according to " The instructions for the ultrasonic control of the wheel sets of the wagons in service" issued by REFER RA in 1993.

D.4. The functioning of the rolling stock and of the technical installations

The state of the railway infrastructure, of the signalling and communications system:

- at the moment of the railway incident occurrence to Zavideni railway station the situation concerning the tracks was the following:
- available tracks: 5;
- busy tracks: I, 2, 3 and 4;
- it weren't closed tracks;
- the state of the signals: good by observing the visibility conditions imposed by the regulations in force;
- the state of the point switches: good;
- the state of the interlocking : good;
- the state of the telecommunications devices: good;
- the state of the track at the place and near the railway incident place : in a straight line;

The wagon no. 31535494306-2 is open freight wagon self discharging type Eacs, for the freight transport in bulk and common goods, being equipped with bogies Y25Cs and automatic brake type KE-GP. The load capacity of the wagon is of 58 tons, the load on the axle being of 20 tons. The wagon is the property of SNTFM „ CFR Marfa" SA. The last repair of the wagon type RK (capital repair) - was performed in July 2004 by SC MEVA SA Drobeta Turnu- Severin. According to the inscriptions from the wagon, to the axle box that was set on the broken axle journal was performed an intervention after the capital repair from August 2007 when was performed the circulation inspection to SC CFR IRV Constanta SA - IRV Petrosani Department. On the occasion of the wagon inspection after the railway incident occurrence the following were found:

- the axle box didn't present the manufacturer seals and other seals;
- were found the identification labels of the screws from the axle box cover on which is stamped the manufacturer and the registration number of the axle;
- the box was presenting a deformation and aspect of melted material as result of the friction due to the breaking;
- when the box was opened was found that is sufficient grease with normal aspect showing a correct functioning of the roller bearings without tracks of irregular heating.
- when verifying the roller bearings from the box was found that these were slightly rotating;

The axle with the registration number 3836632 has the number 14 is a part of the charge 311561, the charge being composed of 52 axis axles.

From this charge, the axis axle no.16 was used for tests and destructive examinations to SC SMR SA Bals.

The working drawing of the wheel set was A 920 M/1.

The axle no. 3836632 of July 16, 2004 was supplied by SC SMR SA Bals with the following documents:

- guarantee certificate no.268 of July 16, 2004 for 18 running gears with a load of 20 tons/axle;
- measurement sheet of axis axle of July 15,2004 for the axle CFR, 20 tons, drawing A 920 M/1;
- measurement sheet of wheel set Ø 920 mm, CFR, code SC-PI-01E/CFR, drawing no. A 920 M/0 for freight wagons with maximum load of 20 tons/ axle of July 15, 2004;
- bulletin of ultrasonic control, report no 15 of July 9, 2004;
- quality certificate for axis axles of the control with magnetic powder no.15 of July 9, 2004.

During operation, the last ultrasonic control of the axle was performed to IRV Petrosani Department on the occasion of performing the circulation inspection to the wagon no.315354943062.
When the tests were done the axle corresponded as results from the measurement sheet of the running gear completed on August 6, 2008.
The axle breaking occurred in an area located at a distance of 217-219 mm from the axle extremity, perpendicular on its longitudinal bar, on connecting the assembling part of the bearing WJ and the shutter.

In order to determine the causes that led to the axle journal breaking, the Romanian Railway Investigating Body requested the performance of a testing report within the Laboratory Department of the Romanian Railway Authority – AFER.
As the technical endowment of the Laboratory Department didn’t allow to perform some tests from which to result the elements that led to deterioration of the mechanical properties of the axle (respectively the decrease of the fatigue strength), the report was previously extended by performing a Technical Report by the “POLITEHNICA” University of Bucharest - Centre for Research and Eco-Metallurgical Expertise – ECOMET.

In the testing report done by the Laboratory Department at the request of the Romanian Railway Investigating Body the following aspects were pointed out:

- on the breaking surface it is noticed that 60 % is a breaking area due to fatigue (progressive) and on 40% a sudden breaking (with material plucking);
- on the breaking area it is an area with a substance of silver colour, circular deposited, of irregular form with a width between 2 and 6 mm and a tape of dark- grey colour of thermo influence , with a width between 8 and 10 mm;
- in the breaking area are marginal cracks;
- on the surface of the axle journal when performing the examinations by ultrasonic control no defects were found;
- when performing the control with penetrant liquids it was found the existence of unexplained circular ring having a cant aspect at the beginning of stress relief clearing both on the broken axle and also on the axle that is not broken;
- after washing with a solvent, then an attack with Nital substance of 5% , the visual examination pointed out the existence of some dark areas in the area of stress relief clearing;
- the control with eddy currents was performed in order to show if exists differences of electro conductibility on the journal surface, between the dark areas and the rest of the surfaces;
- it was put in evidence the difference of hardness on the radial direction on a lateral lamella of the axle between the areas thermo influenced and the material from the middle of the section.

The lateral lamella, used to perform the macro graphic and microscopic analysis of the axle was sampled from the proximity of the site of breaking, pointing out the following conclusions:
- it aren't sulphur segregations that could have led to the breaking and no macro defects of flakes type, material superposition, segregations, macro-inclusions;
- On the section contour is an area thermo influenced, without interruptions, of dark colour on a width of approximately 4 mm;
- to the external surface, on the section contour at micro scale it is noticed that the pearlitic - ferrite constituents with an aspect of column, a structure specific to a molten material. To the limit between this area with a specific structure of molten material and the area in which was put in evidence the specific structure of the basic material of the axle was found a contraction micro crack to solidification of a length of approximately 1,22 mm.

Also on the external surface, in the area thermo influenced with a ferrite structure, some non-metallic inclusions lines were found. The area from the axle material presents a structure with pearlitic-ferrite granules fine recrystallized, being characteristic to a complete recrystallization due to a thermo action.

The results of the tests and examinations contained in the Technical Report performed by "POLITEHNICA" University of Bucharest - Centre for Research and Eco-Metallurgical Expertise – ECOMET were as follows:

- As concerns the tests from the breaking area:
    - when performing a micro visual inspection of the breaking surface it is found that this is specific to a process of breaking to fatigue with multiple cracks;
    - the aspect of the surface is showing that the process of breaking is starting in two areas and the existence of at least two cracks;
    - it is noticed the radial crack growth (as a lens - specific to the breaking at fatigue);
    - deterioration of the breaking surface that took place during the railway event doesn't allow to point out clearly the breaking cracks;
    - from the images put in evidence with the screen microscope it is noticed the existence of the breaking propagation fronts (specific to the breaking at fatigue);
    - The existence in the marginal area of the disc delivered from the breaking area of some micro structural aspects specific to an area of molten material in which it are noticed pores and micro inclusions.

- As concerns the test delivered in close proximity of the breaking area:

- it was noticed on the background of the pearlitic – ferrite microstructure the existence of the MnS inclusions distributed to networks, networks that get also to the surface of the axle journal;
- such of marginal inclusions could form breaking cracks of the axle journal , the lines of inclusions that are emerging to the surface are forming preferential regions of transmission and developing of the micro cracks;
- by the microanalysis of X rays dispersive in energy (EDAX) was put in evidence the distribution of elements Mn, S and Fe and encouraging the development of the micro cracks by the lines and the networks of inclusions of MnS.

The results of the analysis of chemical micro composition by spectrometry of optic emission performed by the spectrometer GNR metal LAB 75-80J put in evidence the exceeding of the sulphur and copper concentration to the tests delivered also from the breaking area and from the adjoining area.

The conclusions were the following:

- it is a breaking due to fatigue;
- the factors that influenced the breaking are :
  - the existence on the axle journal, on cross section of the discontinuous networks of inclusions MnS that had influence on the mechanical properties of the material;
  - the existence of the inclusions lines (were noticed on the cross section of the axle journal) that are emerging to the extremity could have formed breaking cracks and corrosion cracks of the material;
  - the sulphur and copper are in big concentration in comparison with the maximum allowed limits with the following implications:
    i. the sulphur excess attracts more manganese (forming inclusions of MnS) from the existent ferrite into material and as result of this the ferrite becomes poor in manganese, this influencing in a negative way the properties of the material fatigue breaking;
    ii. the presence of the copper over the superior allowed limit is a bad factor meaning that the forging at higher temperatures of 1050º C could led to the formation of superficial cracks and due to the constituent melting rich in copper that is located under the dross bed as result of the steel oxidation and the dross forming, the steel bed from under the dross bed becomes rich in copper.

D.5. Documentation concerning the operating system

The measures taken by the personnel in order to control the traffic and signalling, the exchange of verbal messages related to the railway incident:

When passing through Dragasani railway station, on the first direct line of the freight train no.41651, the movement inspector on duty noticed when performing the visual inspection that to the sixth wagon, from the first wheel in the running way are emerging sparks, informing by radio station the engine driver in order to stop the train.

After the wagon inspection and putting into motion the train, the movement inspector from Dragasani tried again to contact by radio station the engine driver without succeeding, so he informed the movement inspector from Zavideni railway station in order to stop the train and to inspect it.

The movement inspector of Zavideni informed by radio station the engine driver of train no.41651 in order to stop it.

D.6. Man-machine-organization interface

The working program for the involved personnel was: 8 hours for the engine driver and 12 hours for the movement inspectors and the train preparer.

The medical and personal circumstances:

- the movement and operating staff on duty was capable from the medical and psychological point of view for the job that performed it;
- the personnel was examined with alcohol test ampoule and found that it was not under the influence of alcohol.

D.7. Previous railway events with similar character

The railway event is a part of a series of similar events occurred in the freight train circulation relevant for the whole system during 2004-2005, respectively five railway events as follows:

- the railway event occurred on July 15, 2004 on the area of the Railway County of Bucharest, between Videle – Zavestreni railway stations due to the breaking of the axle journal in the connecting area between the shutter and the wedging area from the wheel set no.3835171, type AII from the wagon 31537965905-7;
- the railway accident occurred on July 30, 2004 on the area of the Railway County of Iasi, to Cîmpulung Moldovenesc railway station due to the journal axle breaking in the area of the connecting area between the shutter and the wedging area from the wheel set no.3835112, type AII, from the wagon 31537965898-4;
- the railway event occurred on July 31, 2004 on the area of the Railway County of Craiova , between Zlatarei- Piatra Olt railway stations due to the journal axle breaking in the area of the connecting area between the axle journal and shutter from the wheel set no.3835154, type AII from the wagon no. 31537965885-1;
- the railway accident occurred on August 15, 2004 on the area of the Railway County of Galati, to Gugesti railway station due to the breaking of the axle journal in the connecting area between the axle journal and shutter from the wheel set no. 3835162, type AII from the wagon no. 31537965883-6;
- the railway incident occurred on January 20, 2005 on the area of the Railway County of Constanta, to Basarabi railway station due to the axle journal breaking in the connecting area between the axle journal and the shutter, from the wheel set no. 3834230, type AII , from the wagon no.31535494033-2.

E. ANALYSIS AND CONCLUSIONS

E.1. From the analysis of the Testing Report performed in the Laboratory's Department within the Romanian Railway Authority AFER it wasn't drawn a clear conclusion concerning the cause of the axle breaking:

- although it was put in evidence the existence in the breaking area of an area with a substance of silver colour, circular deposited, of irregular form with a width between 2 and 6 mm and a tape of dark- grey colour of thermo influence , with a width between 8 and 10 mm combined with a difference of electro conductibility on the surface of the axle journal between the area of the stress relief clearing between the axle journal and shutter and the rest of the surfaces when performing the control with eddy currents and a difference of hardness on the radial direction on a lateral lamella of the axle between the areas thermo influenced and the material from the middle of the section it can't be established if the thermo influence occurred during the axis- axle manufacturing process or if this influence appeared as result of the friction occurred in the moment of the axle journal breaking;
- as the breaking surface presents a progressive breaking area (breaking area due to fatigue) of approximately 60 % and a sudden breaking (with material plucking) of approximately on 40% , although according to the same report aren't sulphur segregations that could have influenced the breaking and neither macro defects of flakes type, material superimposed, segregations or macro inclusions;

Taking into consideration all the above , the investigating commission decided to extent the tests to a best performing laboratory and on this occasion were going to be performed also analysis on the chemical composition of the material.

Depending on the performance criteria was chosen the Centre for Research and Eco-Metallurgical Expertise – ECOMET within the " POLITEHNICA" University of Bucharest.

E.2. The extent of the investigations on the breaking surface and of the area adjoining surface breaking to the Centre for Research and Eco-Metallurgical Expertise – ECOMET within the " POLITEHNICA" University of Bucharest led to the establishment of the breaking causes :

- it is a breaking due to fatigue;
- the factors that influenced the breaking are :
  - the existence on the axle journal, on cross section of the discontinuous networks of inclusions MnS that had influence on the mechanical properties of the material;
  - the existence of the inclusions lines (were noticed on the cross section of the axle journal) that are emerging to the extremity could have formed breaking cracks and corrosion cracks of the material;
  - the sulphur and copper are in big concentration in comparison with the maximum allowed limits with the following implications:
    1. i. the sulphur excess attracts more manganese (forming inclusions of MnS) from the existent ferrite into material and as result of this the ferrite becomes poor in manganese, this influencing in a negative way the properties of the material fatigue breaking;
    2. ii. the presence of the copper over the superior allowed limit is a bad factor meaning that the forging at higher temperatures of 1050º C could led to the formation of superficial cracks and due to the constituent melting rich in copper that is located under the dross bed as result of the steel oxidation and the dross forming, the steel bed from under the dross bed becomes rich in copper.

E.3. Direct cause

The direct cause of the railway event occurrence is the breaking of the wheel set no. 3836632 from the wagon no. 31535494306-2 in the area of the stress relief clearing between the axle journal and shutter as result of the decrease of the material fatigue strength against the development of micro cracks in the areas with high density of the networks with manganese sulphide (MnS).

E.4. Underlying causes

- Exceeding the allowed limit for the sulphur concentration (determined values of 0,05 – 0,06% in comparison of the maximum allowed limit 0,04%) which determined the appearance of a discontinuous networks of manganese sulphide inclusions with negative influence on the breaking properties to fatigue of the material.
- Exceeding the allowed limit for the copper concentration (values of 0,35 – 0,37 % in comparison with the maximum allowed limit 0,3%) the noticed inclusions lines can form breaking cracks and corrosion cracks of the material with negative influence on fatigue resistance.

E.5. Root causes

The non-compliance with the minimum imposed conditions on the chemical characteristics of the axles axis established in the reference documents in force at the date of manufacturing (STAS 1947/1990 - Wagons with standard gauge. Axles. General technical conditions of quality and the UIC leaflet 811-1/1987 – Chemical composition, mechanical tests, Axles axis).

F. SAFETY RECOMMENDATIONS

According to the provisions of the Law no.55/2006 in order to improve the railway safety and to prevent some similar railway incidents and events, the Romanian Railway Investigating Body made the following safety recommendations:

1. Withdrawal from circulation of all axles from the charge no.311561 produced by SC SMR SA Bals, from which the axle no.3836632 was a part, for the non-compliance of the conditions established by the UIC leaflet 811-1/87 - Chemical composition, mechanical tests, Axles axis and the rejection of the respective charge.
   SNTFM „ CFR Marfa” SA, other railway undertakings and also owners of wagons equipped with axles from the charge no.311561 will perform investigating actions and will comply with the present recommendation.

2. The performance of a control action by the railway undertakings that have technical departments of reception to the railway suppliers that are offering the working material in order to manufacture metallic elements used to parts and subassemblies from the mechanisms of the railway vehicles that are ensuring the railway safety (the running gear - wheels, axles, bearings and others, the draw and coupling gear - hooks, bars and others, respectively the buffing gear - buffers, springs) by which to identify the cases of non-observance of the own procedures of drawing the material. The conclusions of this control action and also the established measures will be included into a report that will be submitted to the Romanian Railway Authority – AFER the latest August, 2009.

3. On the occasion of the state inspections scheduled by the Romanian Railway Safety Authority it will be supervised the method of implementation of the quality system assurance to the railway suppliers that are offering the working material in order to manufacture metallic elements used to parts and subassemblies from the mechanisms of the railway vehicles that are ensuring the railway safety (the running gear - wheels, axles, bearings and others, the draw and coupling gear - hooks, bars and others, respectively the buffing gear - buffers, springs).

4. The Romanian Railway Notified Body will assess the technical conditions that stood at the basis of granting the technical homologation certificate for the wheel set type AI manufactured by SC SMR Bals SA.

The present Investigating Report will be transmitted to SC SMR Bals SA, to the railway undertakings and to the Romanian Railway Safety Authority.

According to the provisions of the Law no.55/2006 on the railway safety, the Romanian Railway Safety Authority will survey the implementation method of these recommendations.

The members of the investigating commission:

Olaru Mihai - investigator in charge ___________________________

Ciobanu Eugeniu - investigator ______________________________

Zamfirache Marian - investigator ______________________________

Nicolescu Mircea - investigator _______________________________

1. **PERFORMER**: Romanian Railway Notified Body – Laboratories Department

2. **CLIENT**: Romanian Railway Investigating Body – OIFR

3. **TESTING OBJECT**: broken axle journal, end B, in the connection point of stress relief with the obstructing area, with the order number 14, charge 311561, series CFR 3836632, belonging to the wagon no. 31535494306-2, involved in the railway incident from Zavideni, occurred on the 13th of March 2008.

4. **DATE OF THE OBJECT RECEIVE FOR TESTING:** the 13th of August 2008

5. **DATE OF TESTING BEGINING:** te 25th of August 2008
   5.1 Testing was performed: in the laboratories of the Laboratories Department – Rolling Stock Laboratory

5.2 During the testing performance: there were no interruptions

6. **TESTING WAS REQUESTED BY** : Romanian Railway Investigating Body, according to the Note no.7010/182/2008

6.1 Requested tests:
6.1.1 Microscopic checking
6.1.2 Checking with ultrasonic control (CUS);
6.1.3 Control with penetrating liquids;
6.1.4 Control with eddy currents;
6.1.5 Determination of the Brinell hardness on the cross section;
6.1.6 Macro and microscopic metallographic analysis.
6.2 Purpose of the tests was: technical examination

7. **TESTING PRESENTATION**:
   7.1 The testing methods used were: the tests from the points from 6.1.1 to 6.1.6 were performed in accordance with the provisions of the UIC Leaflet 811-1/87 „Technical specification for axles furniture for the motorised and houled rolling stock” (canceled from the 1st of July 2006) and : Instructions for the ultrasonic control, in operation, of the wagons wheel sets” – REFER, 1993.
   7.2 The object tested was: supplied by AFER – OIFR
   7.3 During the storrage, the object for testing: was kept in the laboratory

7.4. During the keeping of the object and tests performance, the environment conditions were: none

7.5. The measuring means used in order to perform the tests are presented in the following table:

No.	**Name of the measuring equipment**	**Series or stock number**	Date of the last metrological checking	**Measuring accuracy**	Tests according to the point
1	Measuring tape 5m	22	02.2006	-	6.1.1
2	Sliding callipers	1030	08.2004	± 0,05 mm	6.1.1
3	Equipment for the static test of the hardness, CV 998	S4 -1-1054-1945/2005	10.2006	cl. 1	6.1.4
4	Metallo graphic microscope AXIOVERT 200 MAT	89	Calibration from Dec 2006	± 0,5 µm	6.1.5

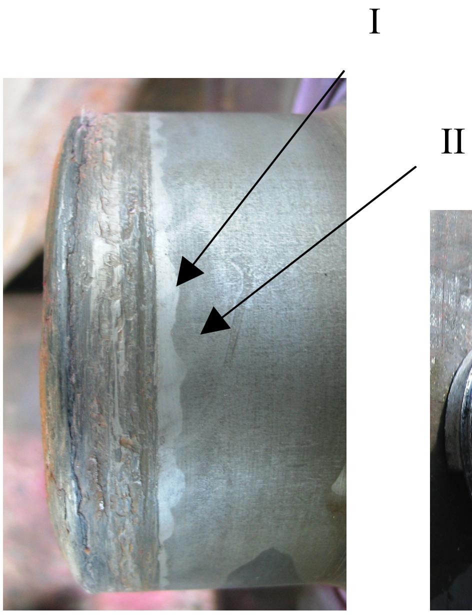
8. TESTING RESULTS:

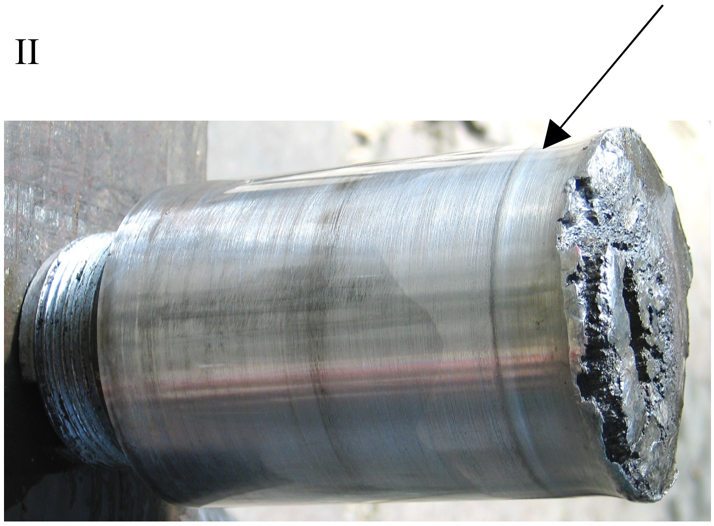
8.1. Microscopic checking

Axle breaking happend in normal plane on its logitudinal axis, by stress relief, under the roller bearing WJ, in the connection point with the cobstructing area – picture 1.

Picture 1

In the picture 2 one can notice a detail of the breaking area, where can be noticed an area with material deposited circular of silver colour, of irregular shape (I), with a breadth between 2 and 6 mm and an adjoining dark grey band (II), of thermo influence (II), with the breadth between 8 and 10 mm.





Picture 2 Picture 3

The broken axle journal of 220 mm length has the end threaded, and at about 35 mm from the breaking point is emphasized a circular area, with an increased height of about 0,15 mm, picture 3. The visible marks on the end of the broken axle journal are: IOB SNTFM 07 04 M90 070453 CFR 38366 32 – picture 4.

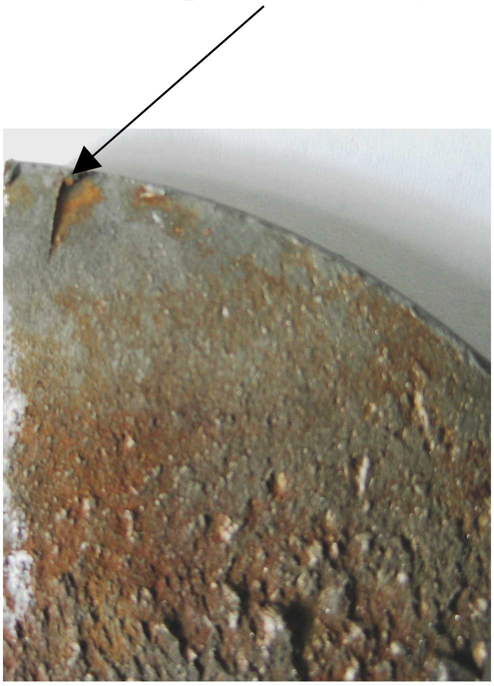
Picture 4 Picture 5

On the opposite end (whole axle journal) are visible the following marks: 1311561 IOB A1N M90 07 04 T 14 – picture 5.
The aspect of one of these two breaking surfaces (breaking) is presented in the picture 6, where can be noticed on about 60% fatigue breaking area (gradual) and on over 40% sudden breaking (with material plucking).

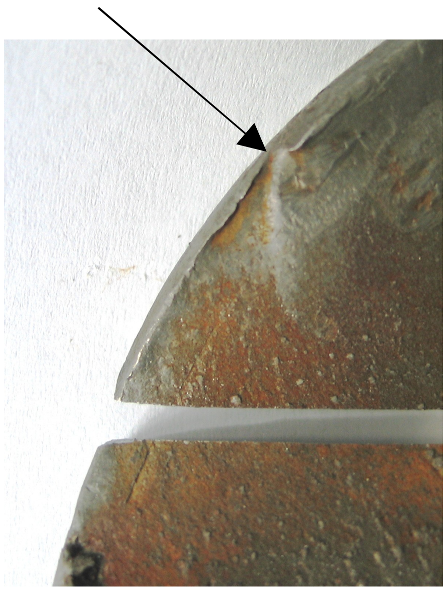
On the section edge can be noticed gradual tendency to break, areas with material deformed and printed form, following the repeated hits of the opened breaking surfaces until the axle journal breaking.

Foto 6

Two details of the edge tendencies to brake of the breaking section (marked with arrows are presented in the pictures 7 and 8).



Picture 7



Picture 8

8.2 Tests with ultrasonic control (CUS):

1. The ultrasonic transparency can not be performed, because both the breaking and the part from the non-broken end do not offer two cross sections, both parallel.

2. The control from the end with the conic special feeler ASW $29^0 – 90$ (series 567) of the axle with the bearing tracks fit up on the axle journal. It can not be performed because the axle had the axle boxes taken off.

3. The control performed on the axle journal surface with the feeler WB $45^0 – 2$ (series 1039) does not show failures.

4. The control performed on the axle journal surface with the feeler WB $35^0 – 2$ (series 5019) does not show failures.

5. The control performed on the axle journal surface with surface wave, with the feeler WB $90^0 – 2$ (series 1039) does not show failures.

Equipments used: Failures detector type USM 35-XS (series 1212a). Feelers used: WB $45^0 – 2$, WB $90^0 – 2$ and ASW $29^0 – 90$.

Callibration bodies:

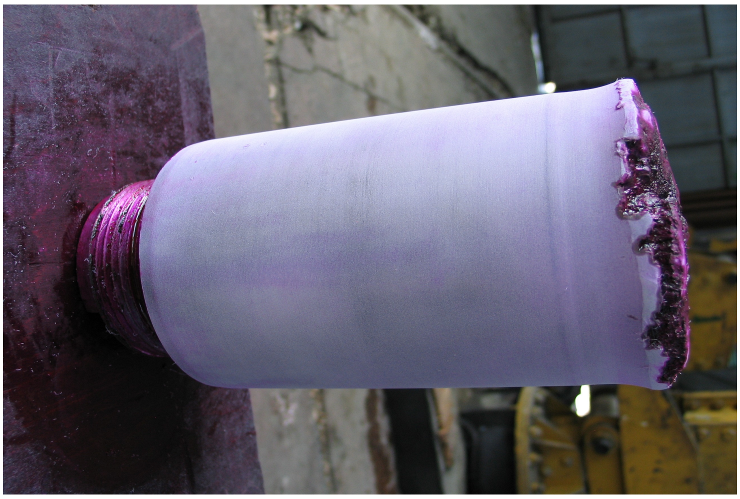
- Semi-cylindrical body with the radius of 50±0,1 mm and the breadth of 25 mm for CUS with cross waves, with gradient incidence of the axles and of the cast wheels
- An axle end type AI (OR1), (axle journal + obstructing area + pressing-on area), with artificial failures (cuts of some deepths at some distances for CUS of the axle journals A I, A II, A III).

8.3 Control with penetrating liquids

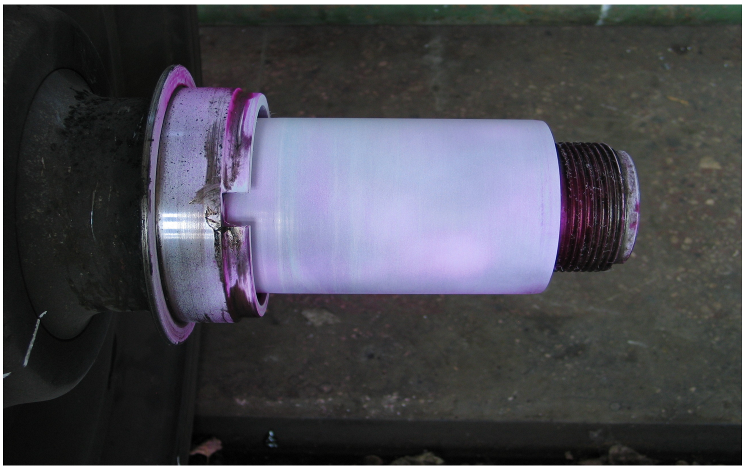
The control with penetrating liquids is used in order to confirm the failures found out during the ultrasonic control (cracks or pores over 1 mm) and shows pores over 1 mm.

Penetrating liquids used: One used a checking system with penetrating liquids type IICd-2 according to the SREN 571-1 from 1999. For this purpose one used: degreasing substance type MR 85, penetrating liquid MR 68C fluorescent red and eluent MR 70, all made by MR Chemie GmbH.

Following the control performance, there were no failures found out, but was noticed the unaccountable presence of a circular ring, as an increased height at the begining of the stress relief, both on the broken axle journal and on the non-broken one.



Picture 9

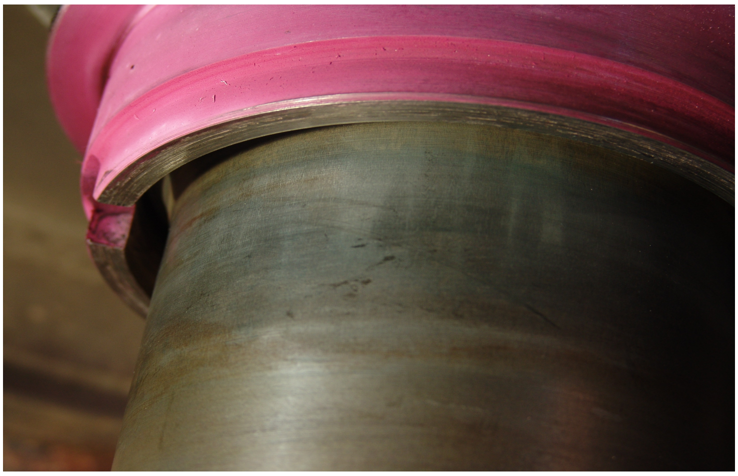


Picture 10

Picture 11

Picture 12

Following the increased height finding out, one proceeds to a wash with solvent, followed by an attack with a Nital substance 5%, at the visual examination were found out dark areas in the stress relief point, as can be seen in the next picture:



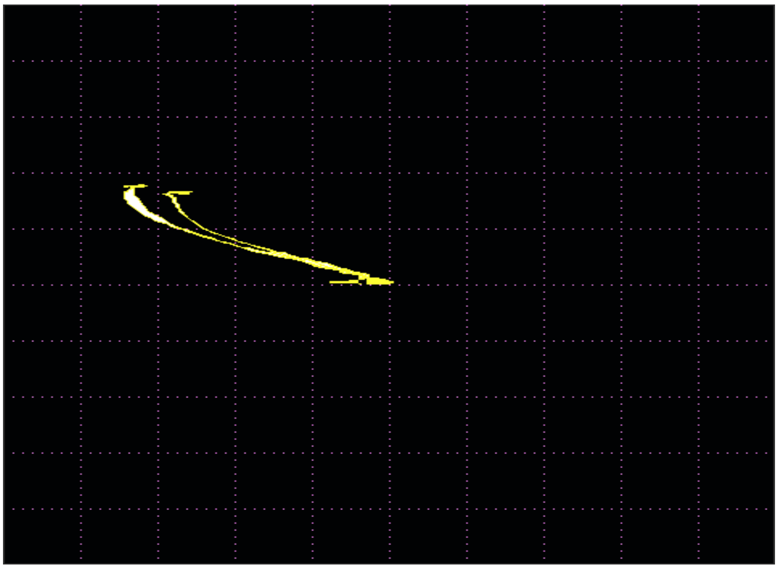
Picture 13

The same situation on the broken side.

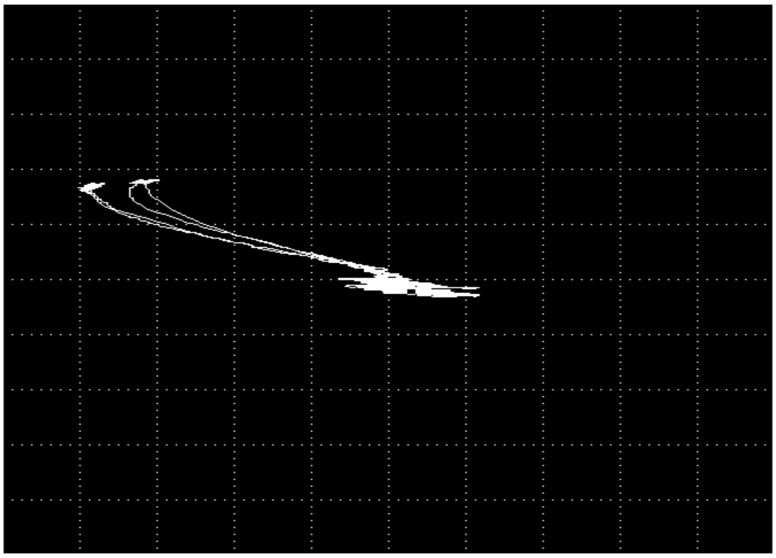
8.4. Control with eddy currents

On the basis of the above mentions, was performed a control with eddy currents in order to point out, if case, electrical conductibility differences on the axle journal surface, between the blakened areas and the rest of surfaces. In this respect was used a failures detector type NORTEC 500C (series N500X1693PO080577), made by OLYMPUS company, using as detection device a proof stick PENCIL of 500 kHz.

Following the control with the equipments above presented, was found out that there was an electrical conductibility difference between the rest of the axle and the stress relief area at the both ends of the wheel set, as results from the next diagram.



Aspect with conductibility difference on the stress relief area against the rest of the axle on the broken part.



Aspect with conductibility difference on the stress relief against the rest of the axle on the non-broken part

8.5. Determination of the Brinell hardness

In order to point out the hardness difference on radial direction, on a cross section of the axle, was determined Brinell hardness, starting from the outside surface to the central surface of the section.

No. stamp	Area for the measurement of the Brinell hardness	Values of the measured Brinell Hardness, **[HBS]**
1	Material on the section edge, in the thermo influence area	177
2	Material on the section edge, on the limit thermo influence area– basis material (middle of the section)	169
3	Material on the section edge, in the thermo influence area	185
4	Material on the section edge, on the limit thermo influence area - basis material (middle of the section)	172
5	Material on the section edge, in the thermo influence area	181
6	Material in the middle of the section	159
7	Material in the middle of the section	157
8	Material in the middle of the section	154
9	Material in the middle of the section	154
10	Material in the middle of the section	154

8.6. Macro and microscopic metallo graphic analysis

The cross section, used to perform the macro graphic and microscopic analaysis of the axle, was taken from the very close part of those broken.
On the cross section surface were performed:

- Baumann test – in order to point out the possible sulphur segregations;
- heat macro-attack in substance of 50% HCL – in order to find out the possible material failures (flakes, macro-blisters macro-segregations, sulphides, macro-inclusions, macro-pores, etc.), failures generated by the superficial thermic treatment or by the processing by plastic deformation (material overlaps , cracks).

After the macro-tests performance, both from the section that contained the breaking and from those close to it, were taken micro-stamps, on whose surfaces were followed :

- structural aspect of the material, by mentioning the type of the thermo treatment applied to the axle, starting from the outside surface to the its central section;
- the presence of the possible material failures or micro thermo treatment.

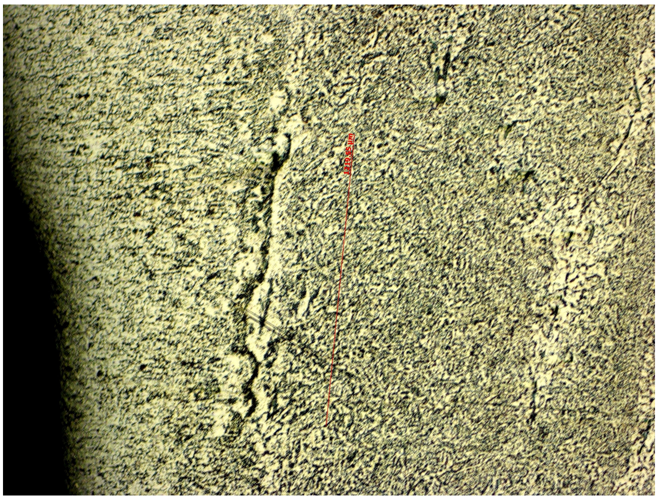
Picture 14

Picture 15

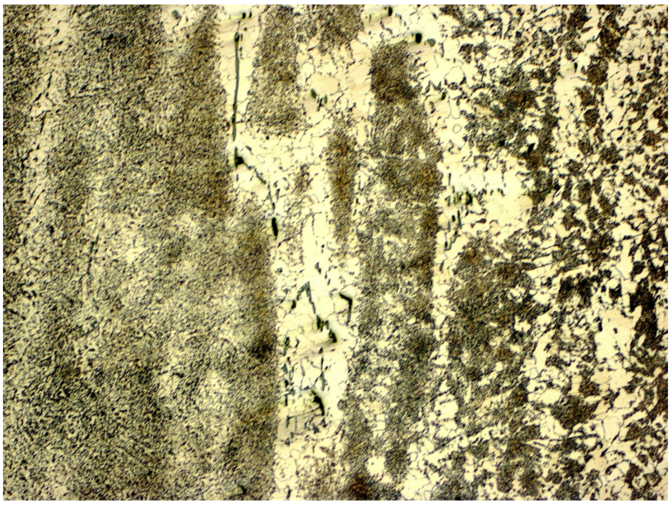
Picture 16

Picture 17

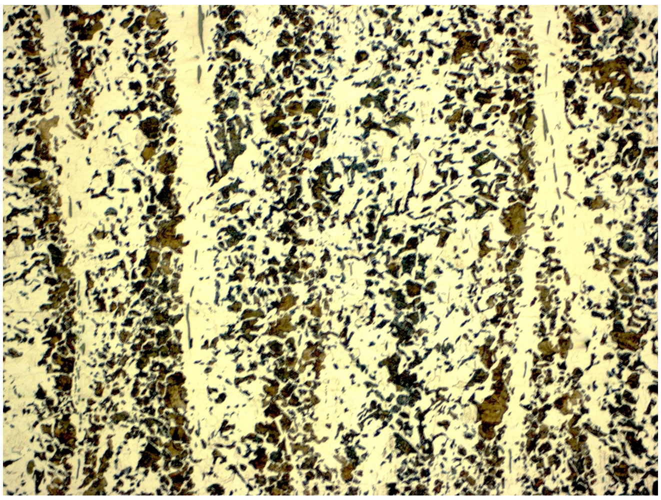
Characteristic type	Conclusions on the analised characteristic	Picture	Conditions established by the UIC Leaflet 811/1-87 for the analised characteristic
Macrographic and macroscopic analysis			
Baumann stamp	• Sulphur uniform ditribution on the cross section, without segregations. The image ranges among the limit images included in the enclosed album at the leaflet.	14	Point 6.2.2.4 – The image obtained has not to present failures more visible than those presented in the limit images included in the enclosed album at the leaflet
Macro aspect of the cross section after the heat attack in substance of 50% HCL	• Without macro-failures type flakes, material overlaps, segregations, macro-inclusions, cracks One can notice a central porosity with points= 1 On the section outline one can see, detailed, a thermic influence area, without interruptions, of dark colour, on a breadth of about 4 mm	15 16 17	Point 6.2.2.3 – After polishing, the examined surface has not to present any continuity solution
Microscopic analysis			
Characteristic type	Conclusions on the analised characteristic	Picture	Conditions established by the UIC Leaflet 811/1-87 for the analised characteristic
The structure at the outside cylindrical surface	• On the outline of the section was found out , at micro level, column pearlite- ferrite constituents, structure specific to a melted material (A). On the edge deposited material (A) – basis material (B), one found out a contraction micro-crack of about 1,22 mm length. • In the thermic influenced area, in the conditions of a ferrite structure, one pointed out the presence of some non-metallic inclusions series. Area (B) from the axle material has grain structure pearlite-ferrite fine recrystallised, being typical to a total recrystallization due to a thermo action.	18 19	Point 7.8.2.2 – Any welding, cutting/burning, heating, any re-building up by metallization, chemical or electrodepositions also any correction to hide a failures are strictly forbidden and lead to the whole lot refuse.
The structure of the axle material in the central section	• The pearlite-ferrite structure as rows, specific to a heat plastic deformed steel and submitted to a normalizing thermo treatment. The size of the structural composition corresponds to the grain value 7-8, so under the stipulated value 5.	19C 20	Point 6.2.2.2 – The normalized, axles structure has to be uniform and specific to the ordered thermo treatment. The size of the pearlite grain determined according to the SR ISO 643 has not to be over the value 5.

A  B

Picture 18 - (100:1), atac

B  C

Picture 19 – (100:1), atac



Picture 20 – (100:1), atac

9. SUB-CONTRACTORS IDENTIFICATION – none

10. OTHER INFORMATION:

a) **The report was drawn up in 4 copies, handed in as follows**:
- copies 1, 2 and 3 to Romanian Railway Investigating Body – OIFR
- copy 4 to Romanian Railway Notified Body – Laboratories Department

b) **Opinions, interpratations** : between 2004 – 2006, AFER performed technical examinations for the axles no. CFR 383112, charge 511969, railway event Campulung Moldovenesc – 2004; 3835154, charge 511970, railway event Zlatareni – 2004 and 3834212, charge 511973, railway event Basarabi – 2005, that broke in the thermo influenced points of the axle journal.

Attentions:

11.1 This report may be used only for the purpose stipulated at the point 6.2. The presented results at the point 8 concerned only the object presented by AFER and tested.

11.2 The extrapolation of the testing results to the characteristics of the lot, charge or to the manufacturing quantity from witch were taken the objects submitted to tests, is done only by the products supplier and the customer and only when it was asked to establish the quality of some lots, charges or manufacturing quantities.

11.3 The report may be completely and only upon the drawer agreement, Romanian Railway Notified Body – Laboratories Department

DRAWN UP

ing. Valeriu CRUCEANU

ing. Veronica NICOLAOS

VERIFIED

Chief of Laboratories Department

ing. Ion SIMION

APPROVAL

DIRECTOR

ROMANIAN RAILWAY NOTIFIED BODY

ing. Mircea Cristian ARNĂUTU

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TECHNICAL REPORT

Extension of the investigations on the breaking surface and on the adjoining area of the breaking surface of the broken axle at the wheel 5 of the wagon no. 315354943062, from the freight train nr. 41651, belonging to Romanian Railway Freight Company "CFR Marfa " SA, involved in the railway incident from the 13th of March, 2008 in the Railway County Craiova area

BENEFICIARY: Romanian Railway Authority – AFER
AFER order no. 1080/870/14.04.2009

DIRECTOR UPB – CCEEM
Christian PREDESCU

Scientific responsible,
Eugeniu VASILE

MAY 2009

1. **OBJECT**: extension of the investigations on the breaking surface and on the adjoining area of the breaking surface of the broken axle from the wheel 5 of the wagon no. 315354943062, from the freight train 41651, belonging to Romanian Railway Freight Company „CFR Marfa" SA, involved in the railway incident from the 13th of March 2008, in the Railway County Craiova area.

2. BENEFICIARY: ROMANIAN RAILWAY AUTHORITY – AFER

3. INVESTIGATION METHODS AND TECHNICS

3.1 Visual macroscopic examination by optical stereomicroscopic and electronic scan microscopy (SEM) at small zooms, at the electronic scan microscope QUANT INSPECT F;

3.2 Microscopic examination of the breaking surface and of the material from its adjoining area at the same electronic microscope;

3.3 Material investigation by X-ray microanalysis energy dispersive (EDAX) in order to characterized it, from the micro-composition point of view;

3.4 The chemical analysis by the optical emission spectrometry, made on different samples drawn from the adjoining area of the breaking surface, was performed with the equipment GNR METALAB (authorized by RENAR).

4. RESULTS

4.1 Macro-vision examination of the breaking surface of the axle journal

In the picture no. 1 is presented the breaking surface of the axle journal, consisting in parts (samples), cuts from the axle journal section as disc, containing the breaking surface. At the performer (ECOMED) was cut only the sample 1.4 from the picture 1, the other sections from this disc was being cut by the customer before starting this investigation.

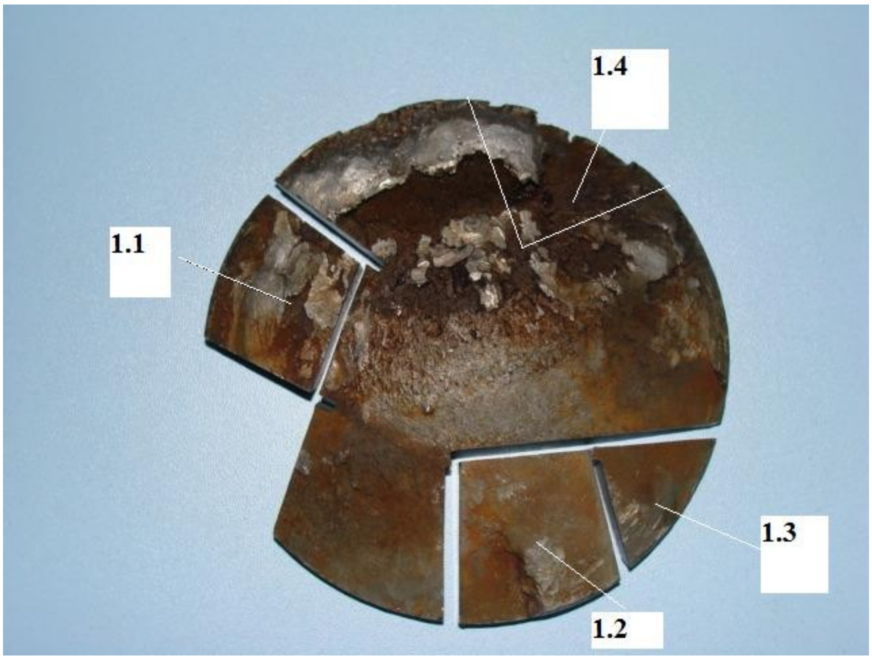


Fig. 1

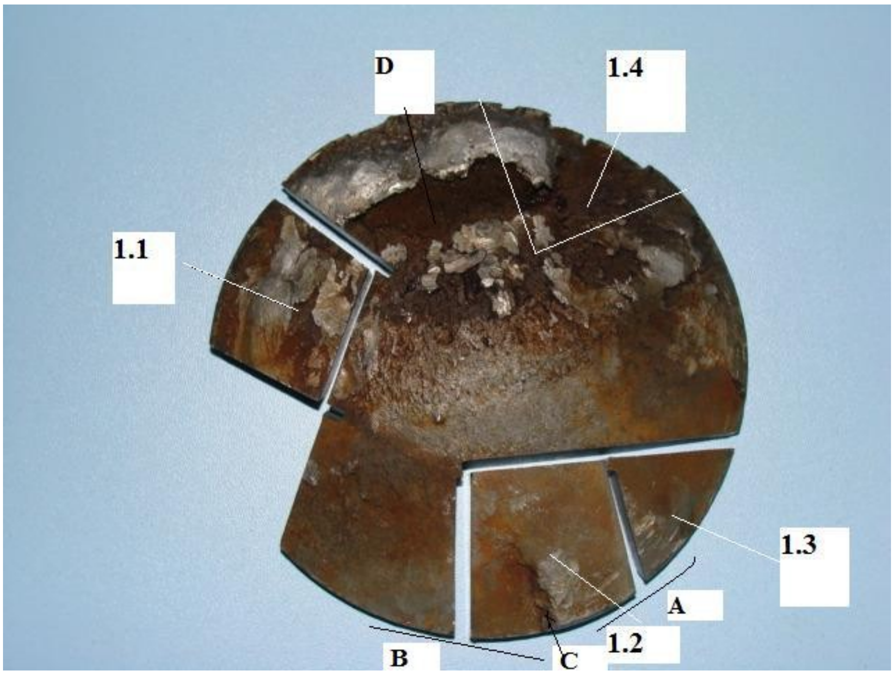


Fig 1a

The aspect of the breaking surface is characteristic to a fatigue breaking process with multiple cracks. Deterioration both of the breaking surface and of the edge of the breaking surface (axle journal exterior) that happened either during the railway event or in the process of drawing and keeping of the samples does not allow to identifying clearly the breaking cracks.

The surface aspect suggests the beginning of the breaking process (and so at least 2 cracks) first from the area A (very deteriorated) and then from the area B.

The two breaking processes met in the threshold C that limits them, by the level differences. To the area D, the breaking surface becomes more undulated, this suggesting an increase of the breaking spreading speed up to the area D, where happened the final breaking, with material plucking.

The sample 1.2 contains a part of the initial breaking (area B). The radial spreading (as lens) of the breaking in the area B looks central on the point E of the sample 1.2.

The image of the electronic scan microscopy (picture 2) has a part of the area B of the breaking starting. In the point E (maybe one of the cracks) the visible mechanical deterioration does not permit to identify the crack. One can see the existence of the fronts F1, F2, F3 of the breaking spreading speed change, specific to a fatigue breaking.

In the picture no. 2, the edge corresponding to the axle journal outer surface is distorted from the mechanical point of view, in a deep of about 0,3 – 0,4 mm (maybe after the axle journal breaking), having cracks and also material detachments to the inside of the breaking surface.

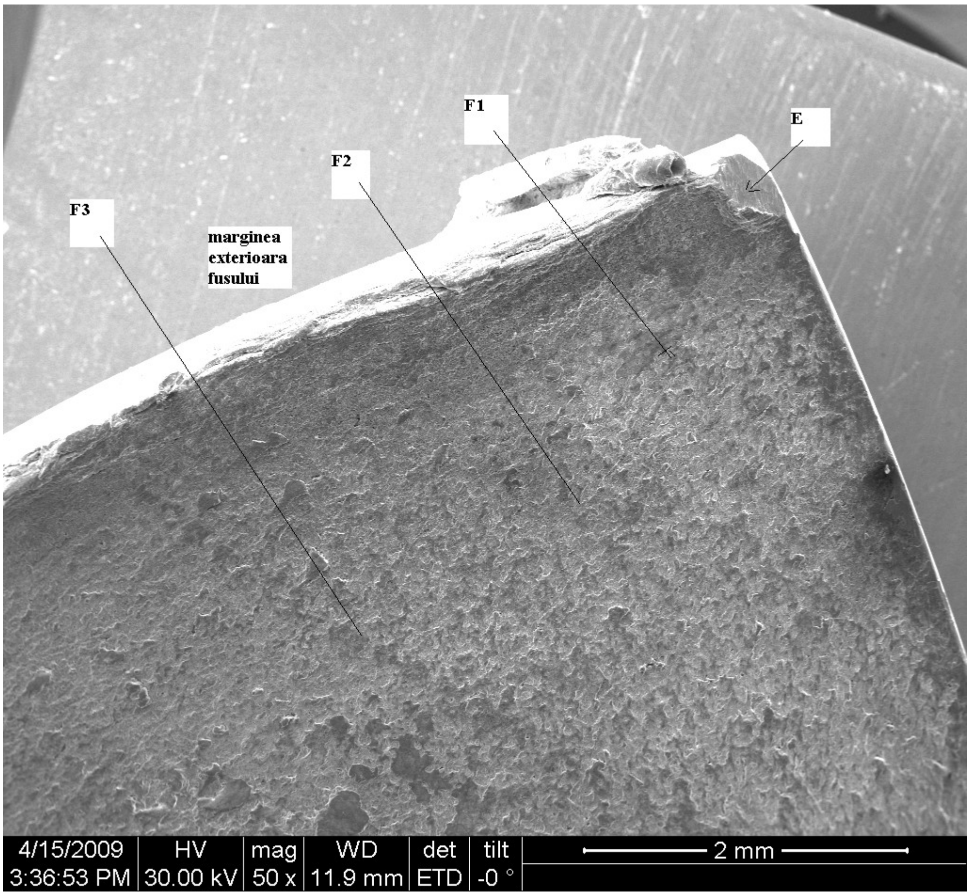
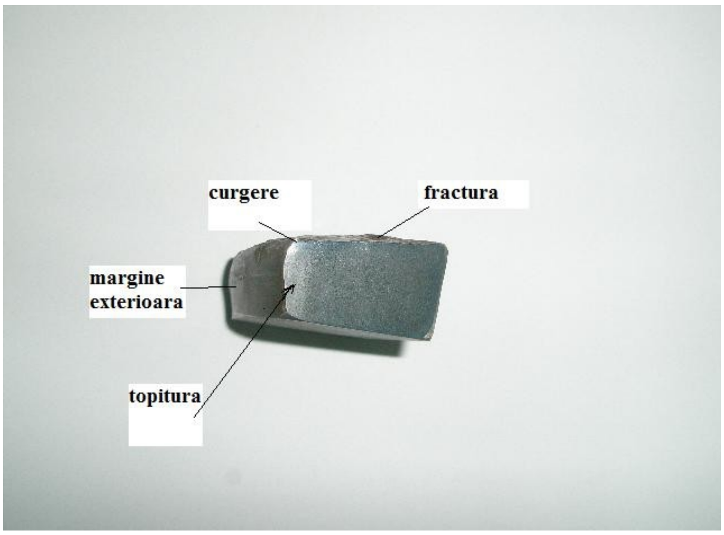


Fig. 2

During the visual inspection of the disc outer surface (cut from the axle journal) that contains the breaking surface was identified a change of its thickness. This is observed (picture 3) in the cross section of the sample 1.1 (see picture 1) from the final breaking area, section made at the performer in order to watch the micro-structure in the breaking surface area and to characterize the micro-area that contains this dimensional change of the axle journal diameter.

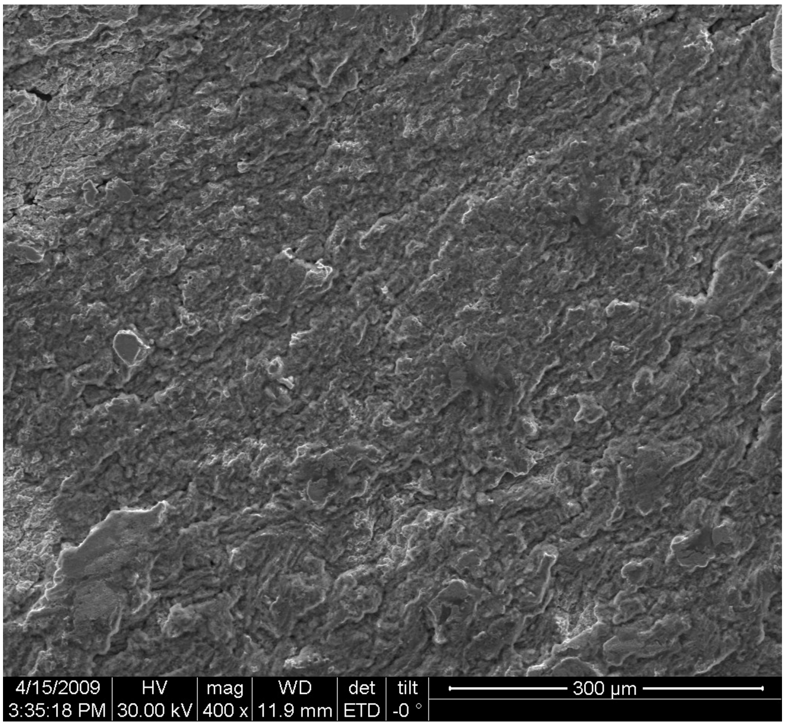


Picture 3 Sample 1.1

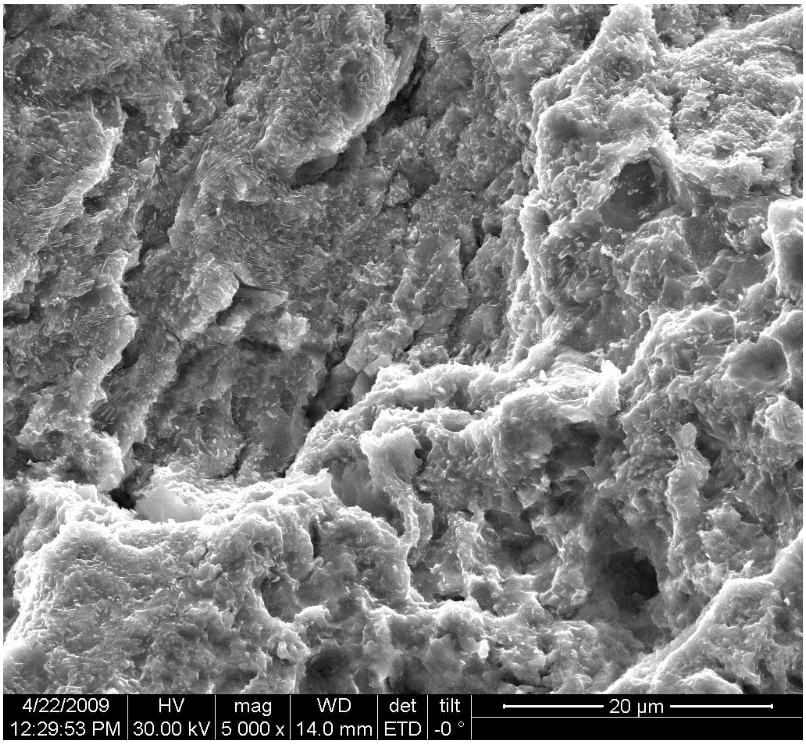
4.2 **Microscopic inspection** was performed with the electronic scan microscope QUANTA INSPECT F. One intended to characterize from the micro-structural point of view the material and to establish the type of the material failures (inclusions, thermo influence) using also the energy dispersive X-ray micro-analysis (EDAX) that allows to establish the local chemical micro-composition and the distribution of the very important elements in interesting micro-areas.

4.2.1 One also tried to characterize from the microscopic point of view the breaking surface. So, in the picture 4, at an increased zoom (x400) is shown that the breaking surface (images from the crack area) is covered by a continuous thick bed of oxides with micro-cracks in the bed. This bed is clearly resulted following the corrosion of the breaking surface after the event.

In order to observe the micro-structural details of the breaking surface one try to remove carefully the oxide bed by replies method. One noticed (picture 5) at a higher zoom (x5000) that, practical, the breaking surface is very corroded (existence of the corrosion pitting (small holes) and even the continuous corrosion of the limits of ferrite-pearlite grains). It is the reason for which one could not obtain micro-structural details of the breaking surface.



Picture.4 The beginning of breaking area – oxide bed (x 400)



Picture.5 Microstructure of the breaking surface after replies pull up – surface very corroded (x 5000)

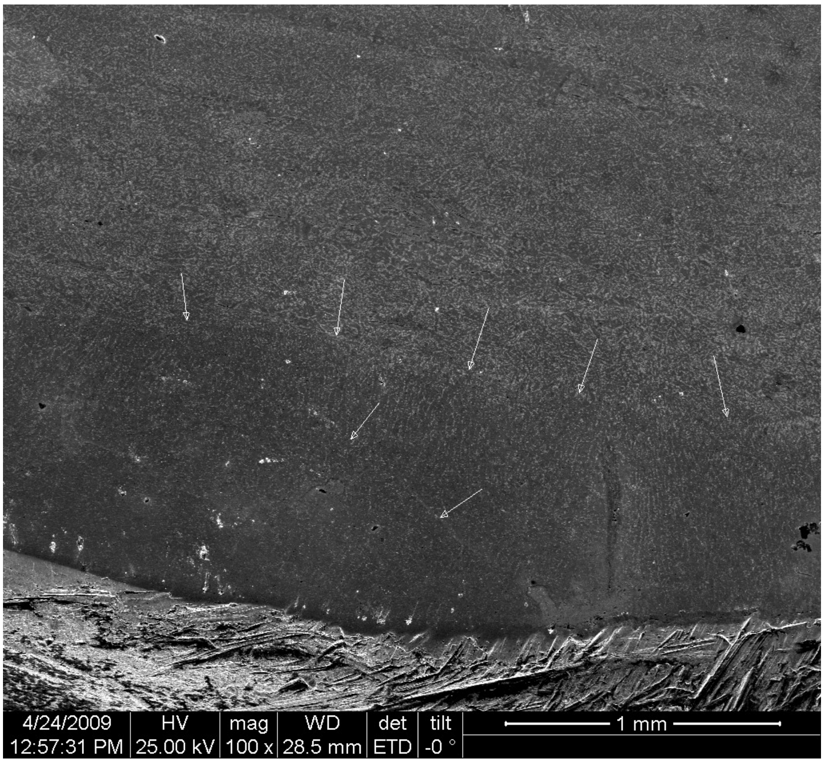
4.2.2 The microscopic description of the micro zone that has a change of the axle journal diameter in the breaking zone

In the picture 3 is observed this micro zone (sample 1.1). In the next images (picture 6) is observed micro-structural details of this micro zone. The edge zone (corresponding to the narrower zone of this section) has micro structural aspects characteristic to an area of local molten material, with the increase direction of the pearlite-ferrite grains perpendicular on the longitudinal axis of the axle. One observes solidification fronts, existence of micro-cracks in the material of this zone.

In the images 7a and b is presented the micro-structure of the basis material of the axle journal – micro-structure disposed on tapes, areas with a lot of pearlite that alternate with those ferrite. One also can notice plastic inclusions of long MnS on the distortion direction.

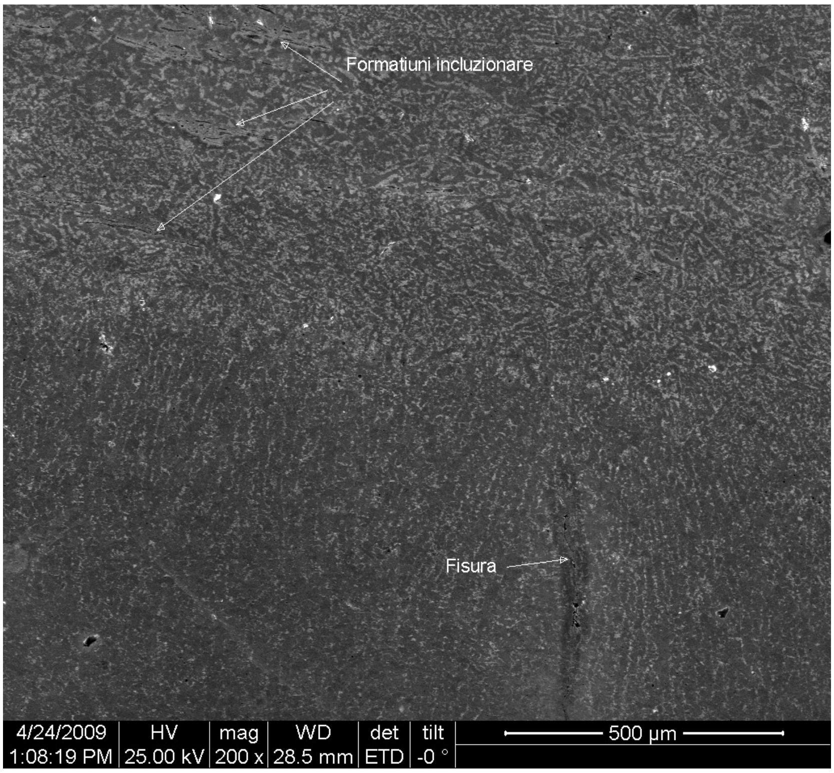
In the thicker zone, one notices a material folding (on the outer surface of the axle journal) to the breaking surface (picture 8a). The images of electronic scan microscopy from the pictures 8b and c put clearly in evidence, long micro-structure (flow) to the breaking surface.

SAMPLE 1.1 (longitudinal section in the disc 1, containing the breaking surface)

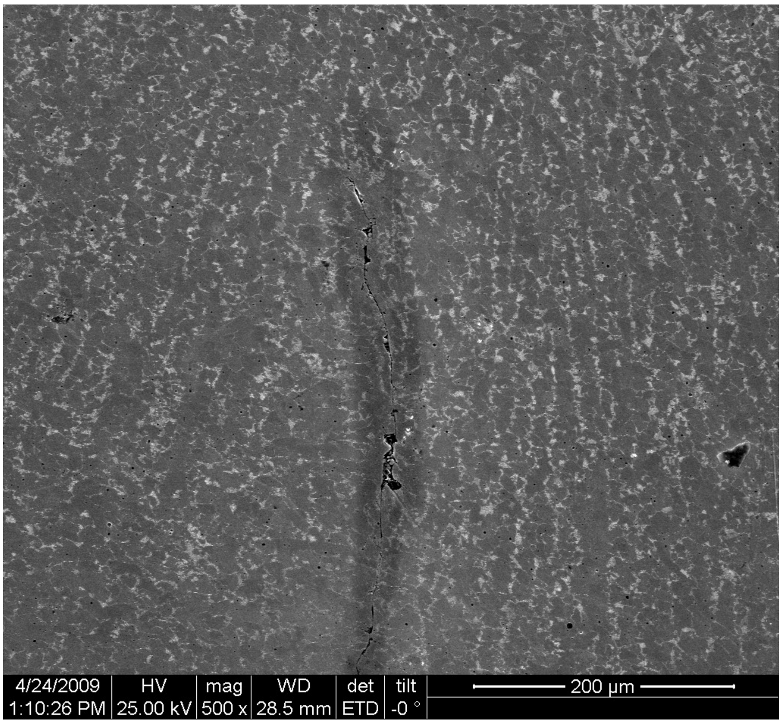


Picture 6a Edge zone putting in evidence the molten material. The arrows show the starting lines of the solidification fronts (x100)

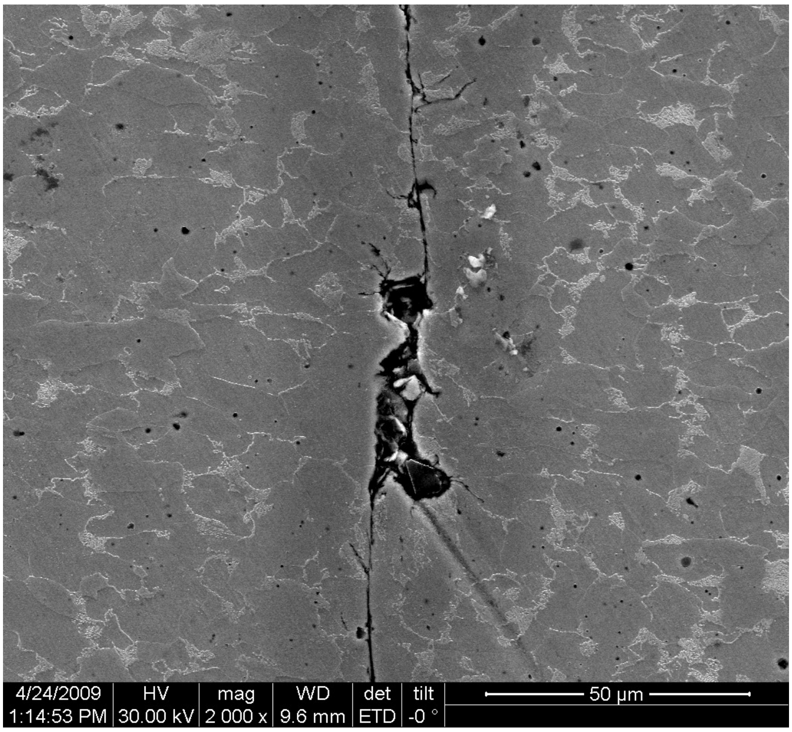
b)



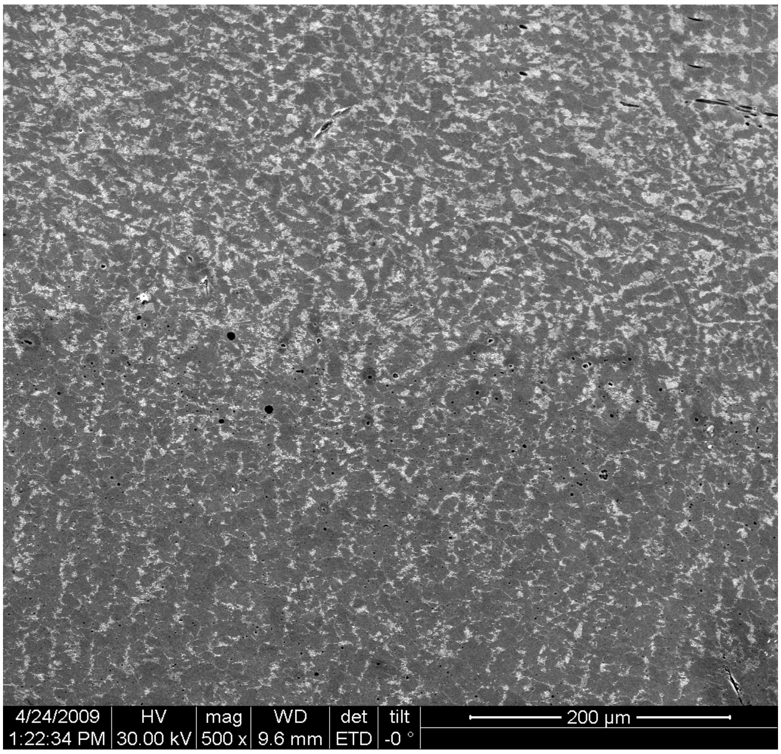
c)



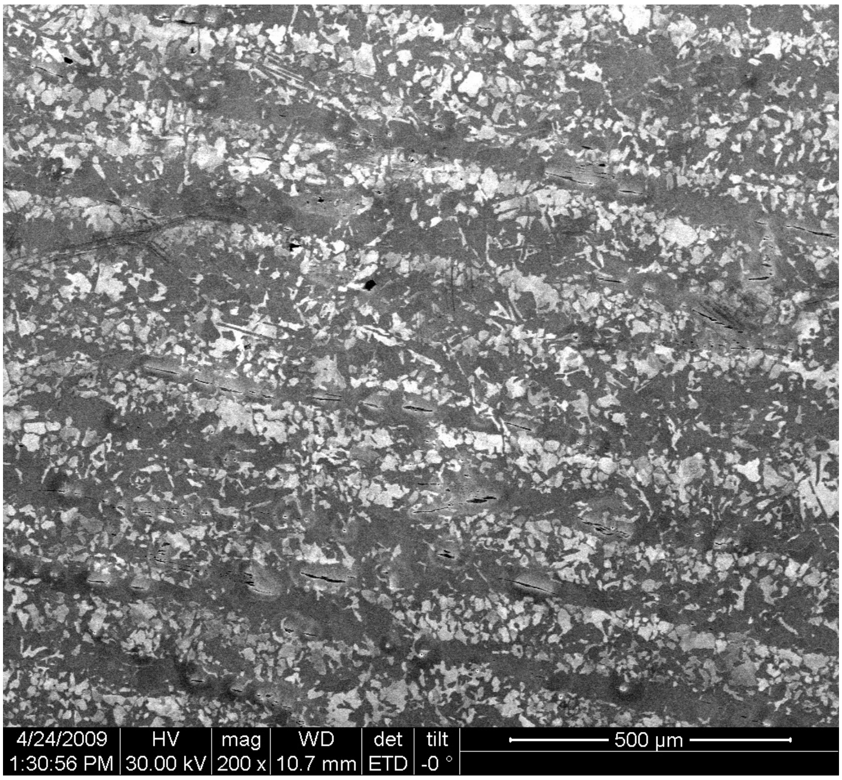
Picture 6 b, c Details from the picture 1.The parallel crack with the temperature gradient at the solidification (x200). One can notice the oriented character of the solidified material structure.



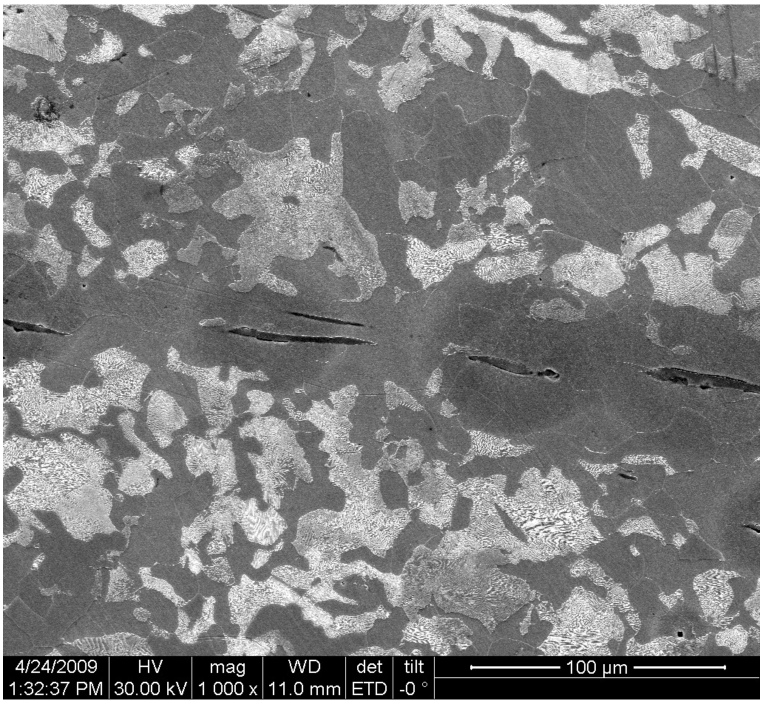
Picture 6d Higher order of zoom putting in evidence the crack intra-granular spreading(x2000).



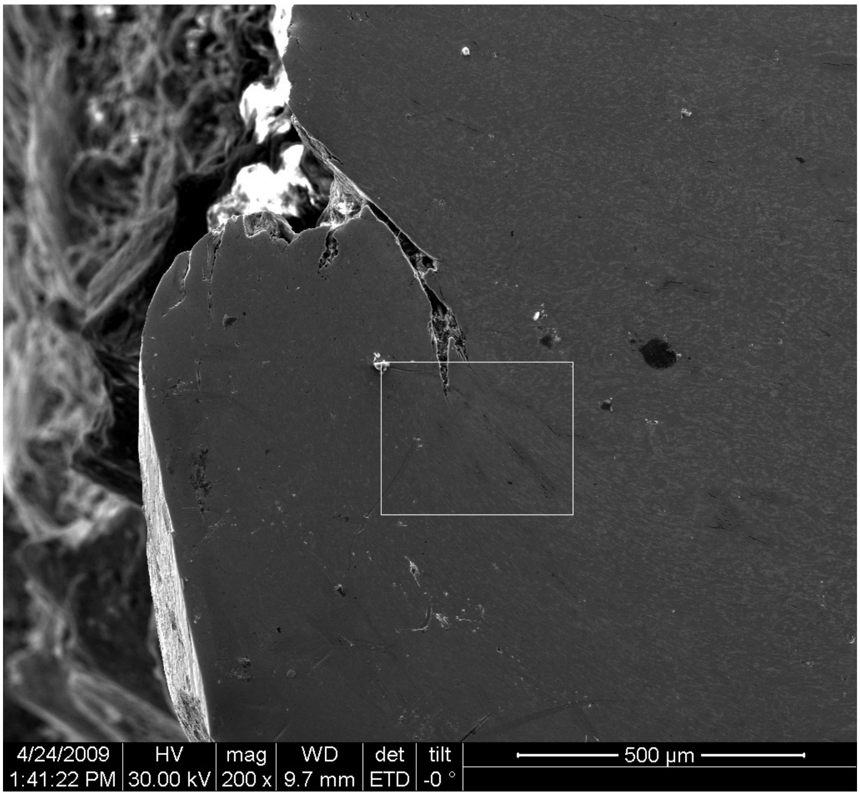
Picture 6e The picture got on the passing point from the basis material to that molten (x500). One can notice the direction difference of the structural formations and more reduce pearlite part in the molten zone (due to the carbon loss). One can also notice pores and micro-inclusions at the interface between these two material volumes.



Picture 7a The micro-structure of the axle journal basis material (x200). Oriented structure, in tapes, with areas with a lot of pearlite alternating with that ferrite. One can notice the presence of plastic inclusions especially in the areas with ferrite.

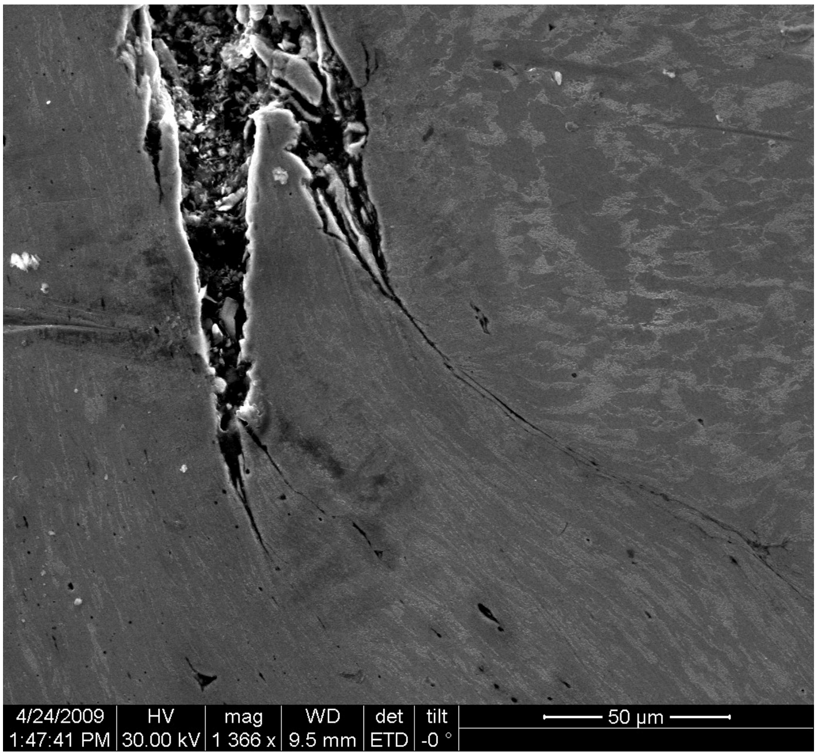


Picture 7b. Detail from the image of the picture 7a. Plastic inclusions placed on the distortion direction (x1000)

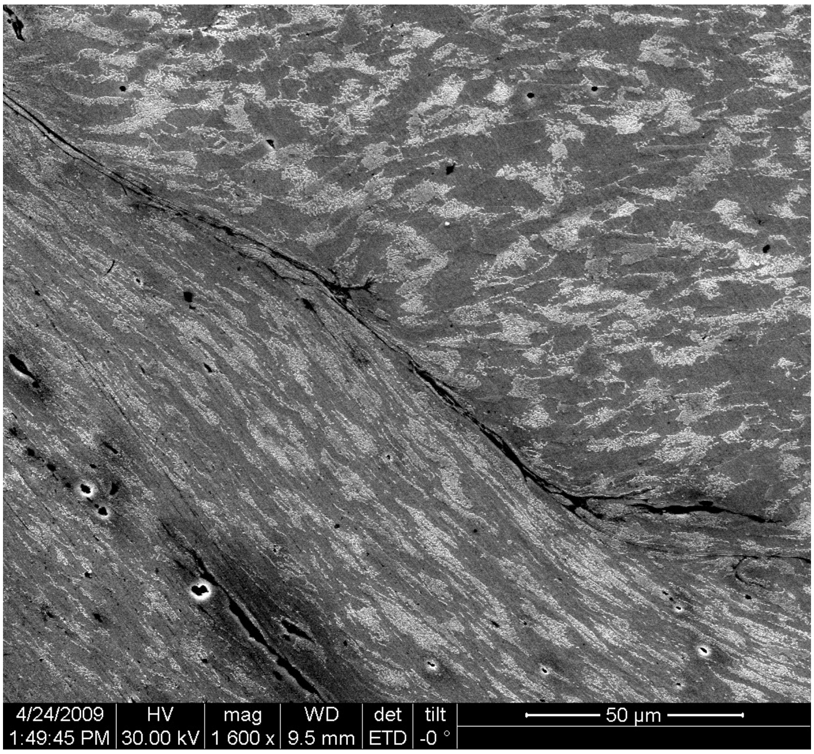


Picture 8a Material „folding”, observed near the breaking surface (x200)

b



c

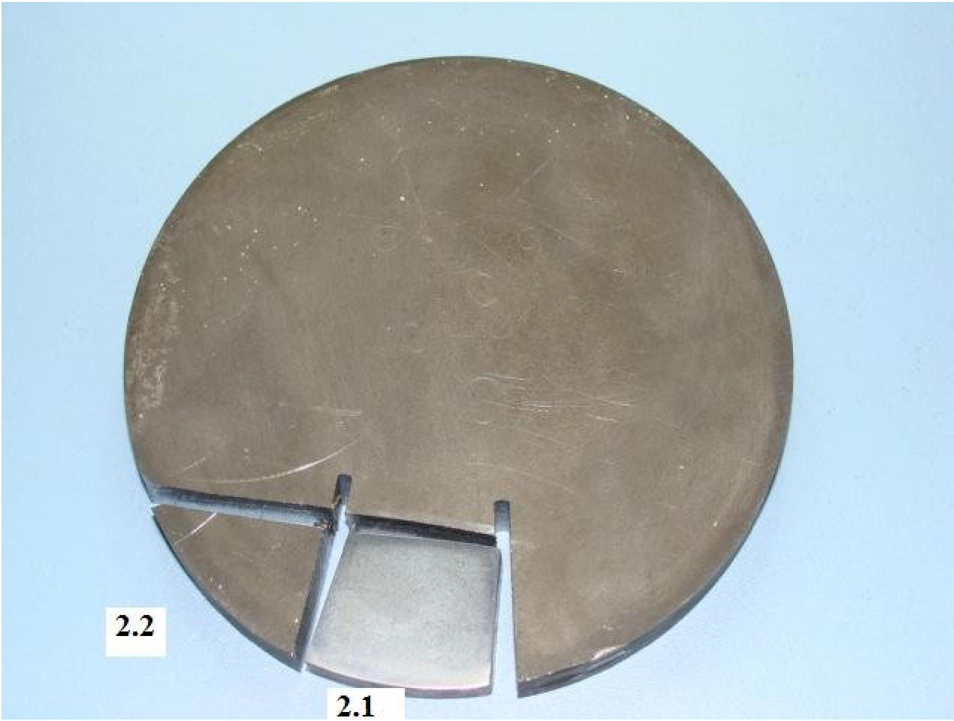


Picture 8 b and c. Details from the picture 8a. The material volumes, with different flow directions (x1366; x1600)

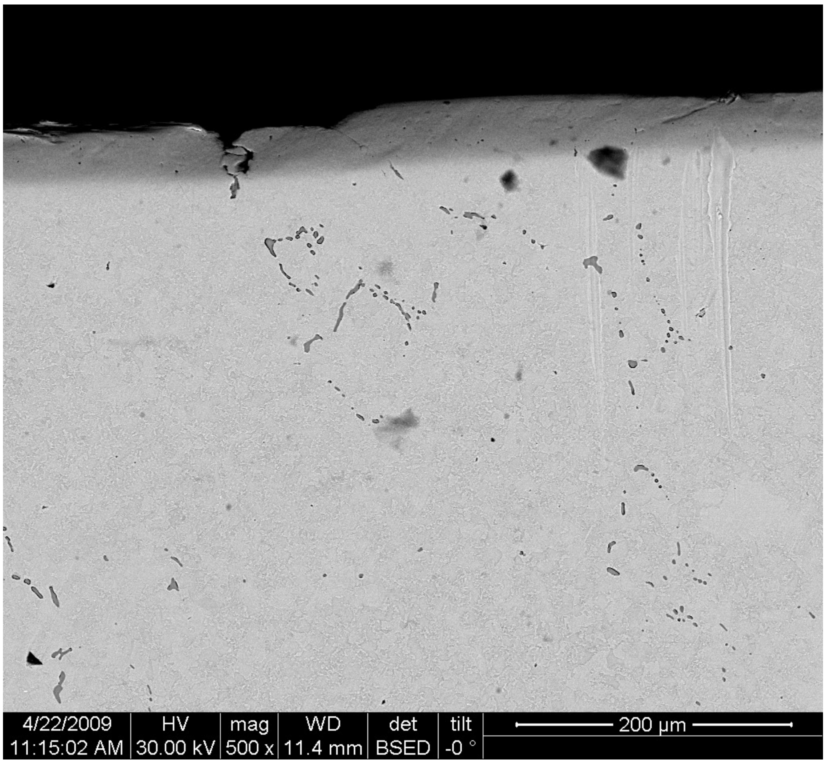
X-ray microanalysis performed on the local melting micro-zone, on the material-folding micro-zone and on the basis material (inside micro-zone) of the axle journal did not show micro-structural differences between these micro-zones.

4.2.3 **Characterization of the material micro-structure in the zone adjoining the breaking surface** was performed on the sample 2.1 picture 9.

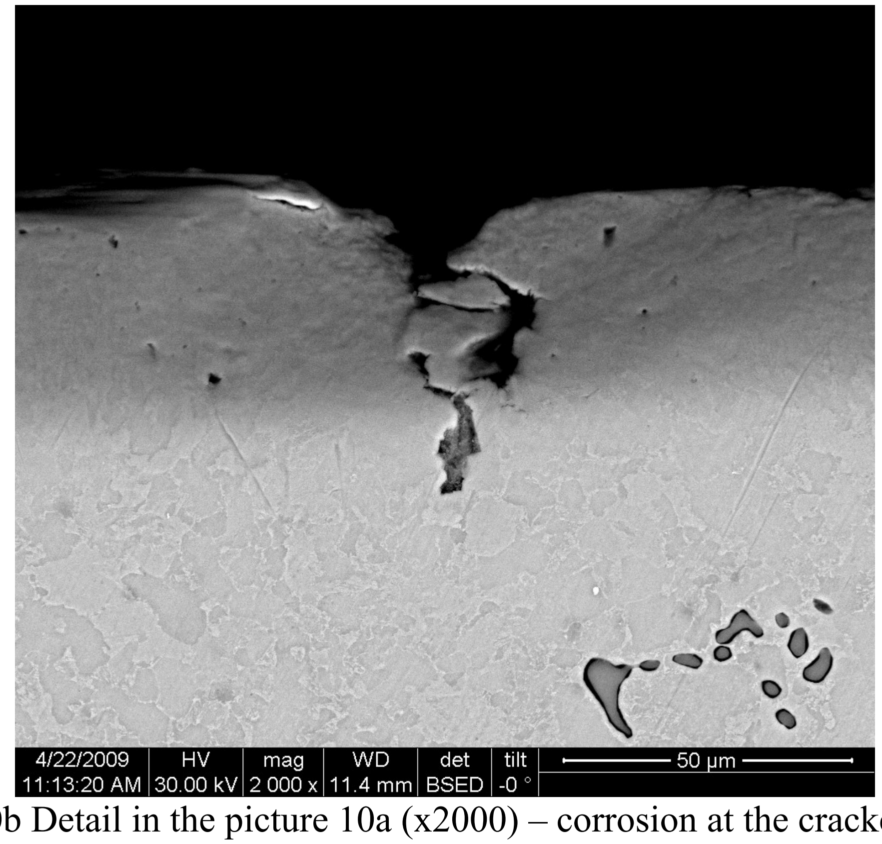
The picture 9 presents a disc cut (by the customer) cross from the axle journal close to the breaking surface.



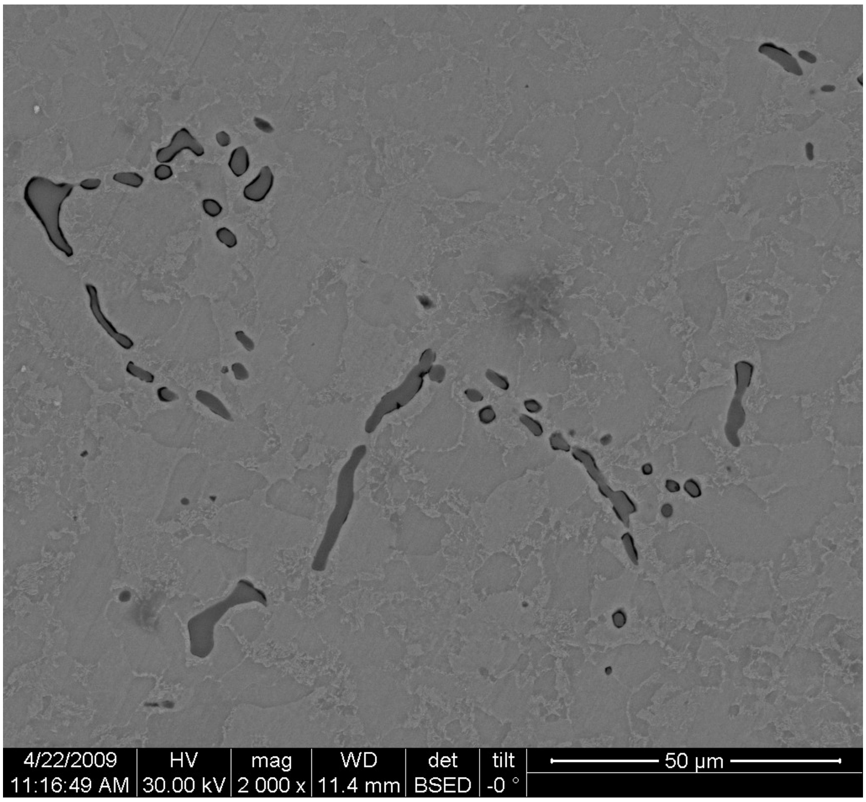
The images from the picture 10 (from a to d), images with secondary electrons retro-scattered, present the micro-structure of the material got on the sample 2.1. One can notice, against the pearlite / ferritie micro-structure, existence of inclusions MnS, irregularly distributed in the material. Unfavourable for its mechanical characteristics, these inclusions are generally grouped in discontinuous networks. One can also notice the existence of MnS inclusions rows that appear on the axle journal surface. Such edge inclusions can be tendencies to fracture of the respective marks in force, the inclusions rows that are come out from the surface are preferential areas for the spreading and development of the micro/cracks.



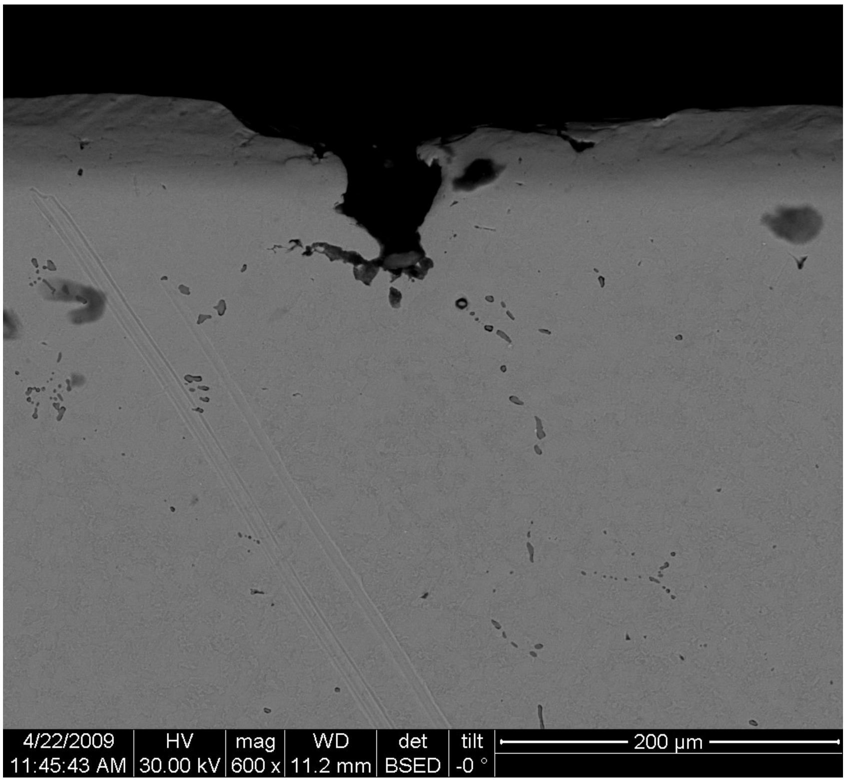
Picture 10a The axle journal micro-structure (image with retro-spread electrons) – cross-sections on the axle journal (x500). MnS inclusions both insulated and in discontinuous networks; MnS inclusions rows that are coming out in the exterior edge of the axle journal.



Picture 10b Detail in the picture 10a (x2000) – corrosion at the cracked edge on inclusions row



Picture 10c Detail in the picture 10a – discontinuous network of MnS inclusions (x2000)

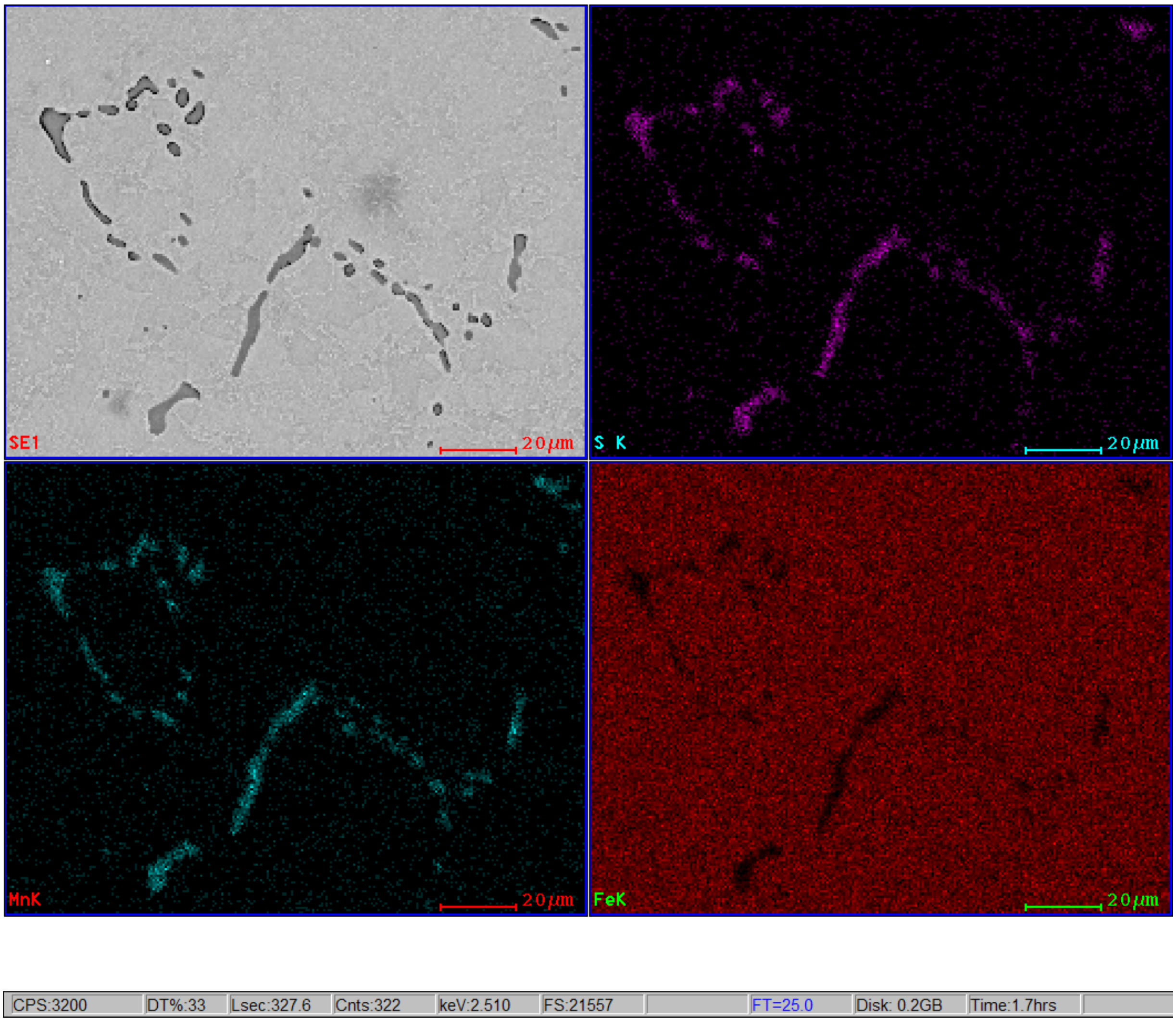


Picture 10d Aspect of other edge micro-zone with the initial corrosion on inclusions row (x600)

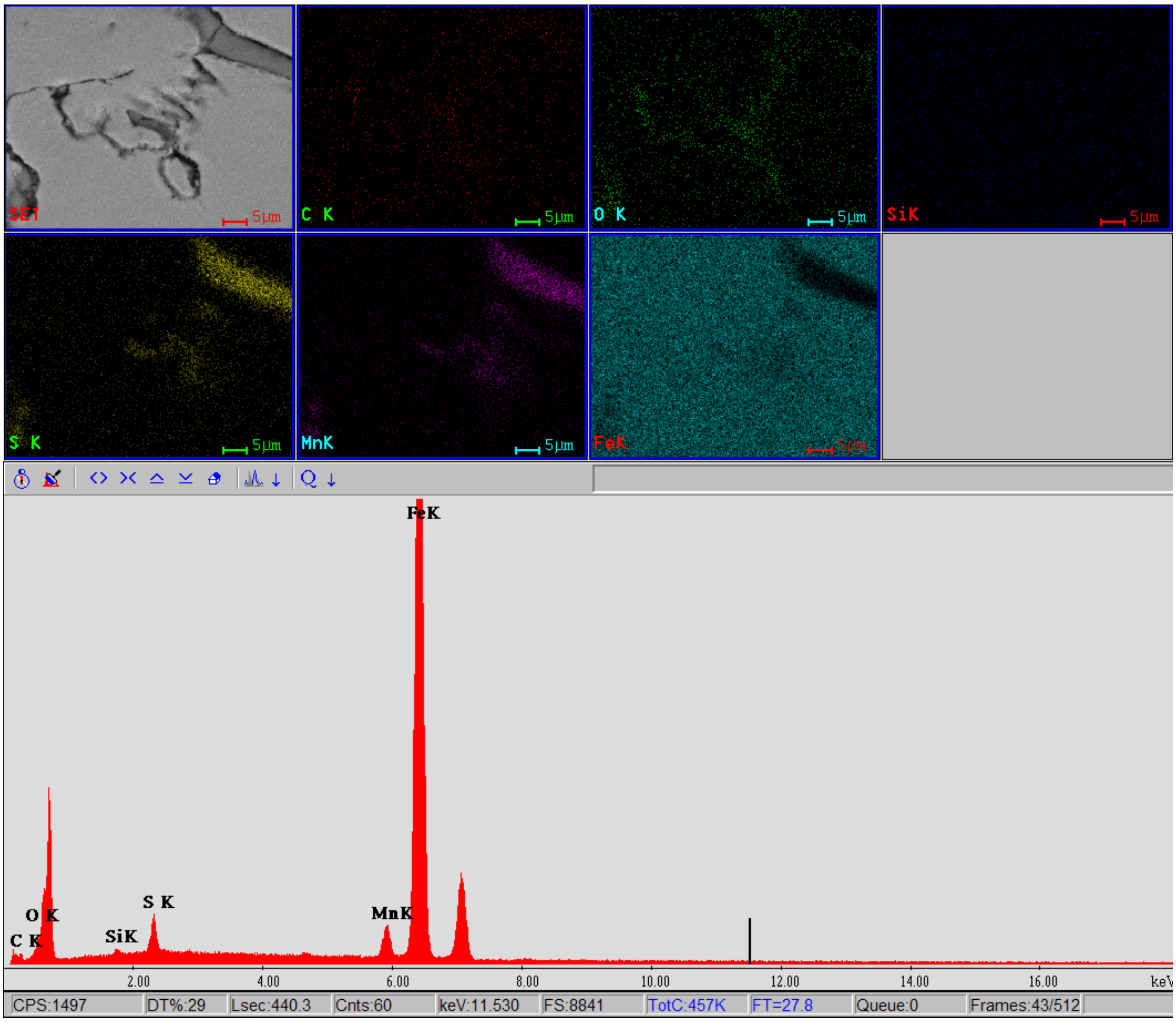
4.2.4 Dispersive x-ray micro-analysis in energy (EDAX) puts in evidence the type of the interesting micro-structural parts from the material.

So in the picture 11 is presented the distribution of the elements Mn, S and Fe in the micro-zone put in evidence in the up right corner of the picture. One can notice the main presence of the elements Mn and S in the long inclusions (manganese sulphide).

Favouring of the micro-cracks development by the MnS inclusions networks rows is proved by the images from the picture 12.



Picture 11 – Distribution of the elements Mn, S and Fe in the zone put in evidence in the up left corner



Picture 12 Distribution of the elements put in evidence by the dispersive X-ray spectrum in energy in the micro-area of the up left corner. The micro-area is adjoining the breaking surface and corresponds to the sample 1.4

4.3 The results of the chemical micro-composition analysis

The results of the chemical micro-composition analysis by the optical emission spectrometry, performed on spectrometer GNR metal LAB 75-80J (authorised by RENAR) are presented in the table bellow for each sample:

Element	Concentration			
	Sample 1.1	Sample 2.1	Sample 2.2	Sample 3.1
C	**0.289**	**0.299**	**0.300**	**0.297**
Si	**0.301**	**0.299**	**0.290**	**0.293**
Mn	**0.893**	**0.921**	**0.911**	**0.908**
P	**0.032**	**0.035**	**0.031**	**0.036**
S	**0.050**	**0.060**	**0.056**	**0.057**
Cr	**0.045**	**0.043**	**0.043**	**0.049**
Mo	**0.010**	**0.008**	**0.007**	**0.004**
Ni	**0.081**	**0.082**	**0.081**	**0.081**
Nb	**0**	**0**	**0**	**0**
Al	**0.008**	**0.008**	**0.008**	**0.008**
Cu	**0.364**	**0.351**	**0.350**	**0.346**
Co	**0.009**	**0.009**	**0.008**	**0.006**
B	**0**	**0**	**0**	**0**
As	**0.013**	**0.012**	**0.009**	**0.011**
Ca	**0.001**	**0.001**	**0.001**	**0.001**
Pb	**0.005**	**0.002**	**0.001**	**0**
Sn	**0.016**	**0.017**	**0.016**	**0.017**
Ti	**0.001**	**0.001**	**0.001**	**0**
V	**0**	**0**	**0**	**0**
W	**0.016**	**0.004**	**0**	**0**
Fe	**97.862**	**97.847**	**97.887**	**97.886**

The analysis of the above presented results shows that the sulphur concentration in the drawn samples from the breaking surface exceeds the up limit of the sulphur concentration accepted in the material (maximum 0,04%). The up limit of the accepted copper concentration (0,3%) is exceeded.

5. CONCLUSIONS

- the visual inspection of the breaking surface shows that this is a fatigue breaking;
- the microscopic inspection of the breaking surface could not supply new elements because the advanced corrosion situation (the corrosion that happened after the event) of the breaking surface;
- the microscopic inspection and the investigation by the X-raze micro-analysis of the material from the zone adjoining the breaking surface of the axle journal puts in evidence the next unfavourable factors:

a) existence in the cross section on the axle journal of the discontinues networks of MnS inclusions, unfavourable factor for the mechanical characteristics of the material;

b) existence of the inclusions rows (observed in cross section on the axle journal) that are coming out in the edge, can be breaking cracks and corrosion cracks of the material;

- analysis of the chemical composition shows that the sulphur (S) is present in the analysed samples in higher composition (from 0,05 to 0,06%) than the maximum accepted limit (0,04%, according to the material norm). Also the higher limit of the copper (Cu) composition (0,3%) is exceeded.

6. REMARKS

Against a material that has sulphur in the concentration accepted by the norm, this sulphur surplus attracts more manganese (forming MnS inclusions) from the ferrite existing in the material and so the reduction of the ferrite in the manganese affects the fatigue breaking characteristics of the material.

The presence of the copper, though the accepted higher limit is slightly exceeded, can be an unfavourable factor. So, forging at temperatures higher than 1050^0 C can lead to the appearance of superficial cracks, even at a copper content of about 0,2%, this due to the melting of the constituent with a lot of copper that is under the scale bed as result of the steel oxidation and scale forming, the steel bed immediately under the scale bed growing rich in copper.

Colectiv de lucru,

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CS1 dr.ing. Eugeniu VASILE