METALLURGICAL EVALUATION BY COMPARISON OF THE C45PBK STEEL (IMPORTED AND NATIONAL RAW MATERIAL) BY FUEL INJECTION SYSTEM PARTS

Sergio Medeiros dos Santos, sergio.santos2@br.bosch.com
Robert Bosch Ltda, Av JK de Oliveira 11800 – Curitiba-Parana 81450902
Alba Regina Turin, alba.turin@br.bosch.com
Robert Bosch Ltda, Av JK de Oliveira 11800 – Curitiba-Parana 81450902
Rogerio Milleo Pitella, rogerio.pitella@br.bosch.com
Robert Bosch Ltda, Av JK de Oliveira 11800 – Curitiba-Parana 81450902
Wanderley Emerson de Brito, wanderley.brito@br.bosch.com
Robert Bosch Ltda, Av JK de Oliveira 11800 – Curitiba-Parana 81450902

Abstract. This work has how objective the metallurgical evaluation by comparison between national raw material and imported raw material of the lead alloyed heat-treatable steel C45PbK. They were tested 04 fuel injection system parts, this parts were submitted by hydraulic pulsation test. Two pieces were national raw material and two pieces were imported raw material. They were realized the following analysis: chemical analysis (spectrometer Spectrolab), Vickers hardness (Stielfelmayer durometer), macrograph (stereoscope and video system VM1040), fractography (scanning electron microscope FEI), non metallic inclusions analysis (image analyzer analysis auto), metallography (optical microscope Olympus BX51M). The obtained results had how principal objective to identify premature failure in the national specimens during the hydraulic pulsation test. They were characterized differences between chemical contents by national raw material and imported raw material. That differences could to push the damage in the part machining process because the elements Silicon, Lead, Aluminun, Sulfur, Nickel and Cupper contribute promote some characteristics and mechanical properties when them dissolve in the alloy.. This inclusions act as nucleator of the cracks abbreviated the useful life of the sample.

***Keywords**: : steel C45PbK, non metallic inclusion, Lead and Sulfur*

1. INTRODUCTION

Among the materials used now in mechanical constructions, they are the metallic alloys and mainly the Iron alloys that they are used broadly. This for being the Iron a metal of easy processing and found abundantly in the earth besides the factor that the iron has real facility in tying the other metallic elements and no metallic, among which it consists as main the Carbon. Due to wide use scale and also the high demands of quality of the market see her need of improvement of the process of production of the ferrous metallic alloys, trying to produce calls "cleaner" with better mechanical properties. The factors that interfere directly on the properties of the Iron alloys they are:

Chemical composition;
Microstructure;
Iron and steel making.

In this study specifically we will be attentive to the iron and steel making and consequently to the chemical composition. The basic element of the composition of the alloy is the Carbon that has direct influence in the microstruture and properties, but other elements of the alloy, that can be coming of the matter excels or especially added, in great or small quantities, as in a cookery revenue, they act on the alloy in the same way, in other words, on the microstructure and properties. In this work we will specifically study alloys of Iron-Carbon, call of steel, that is an alloy where the carbon reaches quantities among 0,008% the approximately 2,11% besides the alloy elements commented on previously. The inclusions non metallic they are usually original of the normal "sludge's" of the production process, that are them, match, Sulfur, Manganese, Silicon and the Aluminum, that they react amongst themselves or with other elements of the alloy forming the inclusions. The formation of these inclusions usually happens in the final phase of deoxidation of the steels. With the need of to develop and to produce steels with larger quality and better properties, it has been concentrated in the last year's specialists efforts so that this improvement is executed. That depending on the use of the component the non metallic inclusion is not a noxious agent, could be even constructive when the inclusions are the promoters of linked defects to the processing and usage of the component. Fado, (2005)

The component studied in this work presents chambers of high pressure, what can present initiate cracks in defects of the machining process, heat treatment, ECM (electrolytic chemical machining) and non metallic inclusion presence in favorable region to the crack initialization.Yang at all (2004)

This work had as objective the comparative evaluation of submitted mechanical components the high pressure made with import and national raw materials and submitted to essay of hydraulic pulsation. The evaluation was accomplished being used methods of optical microscopy, scanning electron microscopy, obtaining like this qualitative chemical composition, morphology and quantity of the inclusions per area unit course, and Vickers hardness and quantitative chemical analysis. Pires, (2000)

2. METHODS AND MATERIALS

2.1. Sample identification:

The analyses were accomplished in two parts made by national raw material (sample A and B and two parts made by imported raw material (sample C and D)-C45PbK:

- Sample A- hydraulic pulsation test - 1600bar- crack with 0,912x10^6 cycles;
- Sample B – hydraulic pulsation test – 1600bar - crack with 1,026x10^6 cycles;
- Sample C – hydraulic pulsation test – 1600bar - crack with 2,690x10^6 cycles;
- Sample D – hydraulic pulsation test – 1600bar - crack with 2,850x10^6 cycles.

2.2. Chemical composition:

In the table 1, we presented the chemical composition specified by the norm DIN IN 10083-1 - material number 1, 0504 and the chemical composition of the samples A, B, C and D, obtained through spectrometry.

Table 1. Chemical composition

Chemical element	Specification (%)	Verified		Δ (%) National x imported
		National (%)	Imported (%)	
C - Carbon	0,45-0,49	0,476	0,453	4,83
Si - Silicon	Máx. 0,40	0,284	0,197	44,0
Mn – Manganese	0,50-0,85	0,756	0,794	4,78
P – Phosphorus	Máx. 0,035	0,023	0,020	13,0
S- Sulfur	0,020-0,040	0,018	0,040	122,0
Pb – Lead	0,15-0,30	0,220	0,160	37,0
Al – Aluminum	0,020-0,050	0,017	0,040	135,0
Mo - Molybdenum	Máx. 0,15	0,037	0,010	270,0
Ni – Nickel	Máx. 0,30	0,037	<0,01	270,0
Cu – Copper	Máx. 0,30	0,208	0,016	1200
Ti – Titanium	Máx. 50ppm	0,003	0,003	0

2.3. Vickers Hardness- HV10:

Course of hardness of 2,00mm of extension was accomplished, starting from the surface, in the core of the crack place.

Table 2 . Hardness HV10

sample	Hardness HV10																				average
mm	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,8	1,9	2,0	
A	190	192	189	189	190	189	187	187	190	188	188	189	189	189	190	191	191	190	191	192	190
B	192	193	194	194	193	194	193	195	196	193	194	192	193	193	193	194	192	192	194	195	194
C	181	177	179	181	183	178	180	180	181	181	181	180	181	181	182	181	182	182	184	183	181
D	180	182	182	180	182	182	182	182	182	181	179	180	183	181	183	182	181	181	179	179	181

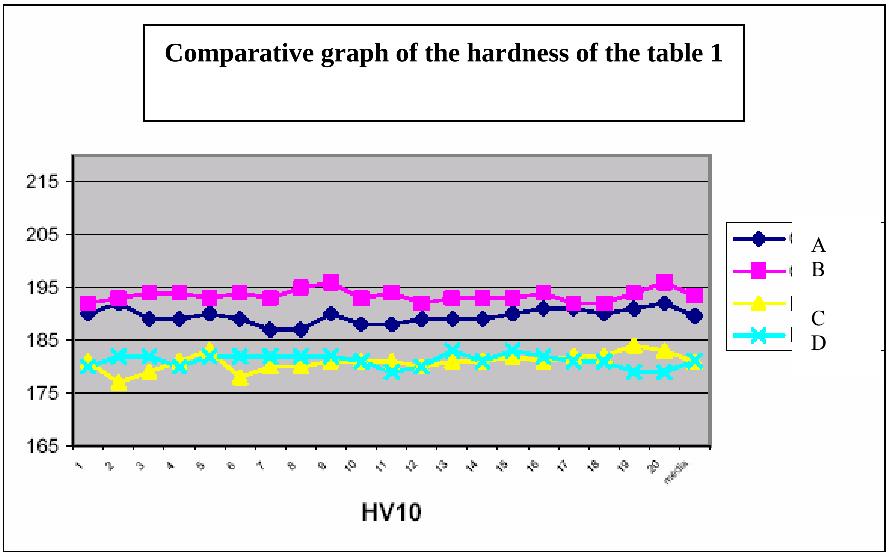

Figure 1. Graph hardness x course

2.4. Brinell Hardness- HB5/750:

The specified hardness : 255HB5/750

Tabela 3: Dureza HB5/750

Sample	Hardness			Average
A	211	215	219	215
B	215	219	215	216
C	211	207	211	210
D	211	207	202	207

2.5. Metallographic:

The samples were analyzed by metallographic microscope Olympus BX51M, after surface preparation. All the samples presented the normalized microstructure contained lamellar perlite and ferrite.Ishikawa (2001).

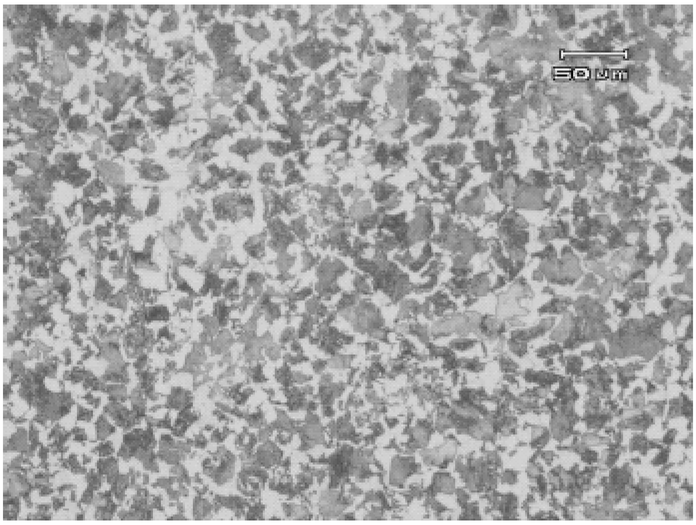

Figure 2. Sample A

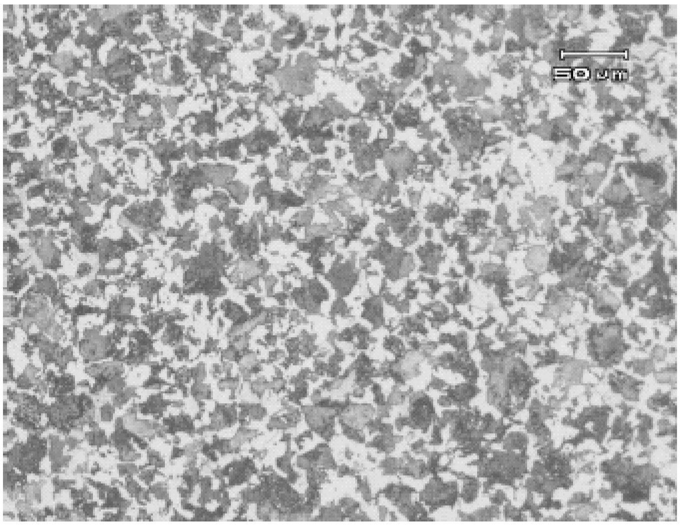

Figure 3. Sample C

2.6. Non Metallic Inclusions of the Pb (Lead) - analysis:

For qualitative and quantitative analysis of the Lead (Pb) non metallic inclusions, the analyzer of images AnalySIS was used, coupled MEV with the system BSE - backscattering, that identify the chemical components through the contrast due to the atomic number. The contrast happens due to the quantity of issue corresponding of electrons of high energy (of the order of 50eV) that increases lineal and quickly with the atomic number of the material to Z=45 and more slowly for heavier electrons. Being possible to use image of backscattering to detect different chemical compositions, that it is the case of the lead inclusions or manganese sulfite in contrast with the bulk of the analyzed steel. Botta (2002).

This analysis was merely comparative, because any norm was not used as limitation for the essay. They were accomplished analyze in 20 tables with enlargement of 100x, measurement an area of ~ 125mm2, of the fractured area of each sample.

Table 3: Pb Nom metallic inclusions

square	PB inclusions (mm^2)	
	National	Imported
01	2,19	4,97
02	3,57	3,23
03	4,13	4,23
04	3,19	4,09
05	3,30	2,48
06	3,47	4,61
07	4,14	2,34
08	3,25	1,09
09	4,27	2,45
10	7,28	4,09
11	8,31	4,85
12	6,32	2,54
13	6,59	2,45
14	7,68	3,35
15	4,44	2,67
16	2,95	2,85
17	2,33	3,56
18	4,27	2,14
19	3,86	2,91
20	3,41	2,86
Total	88,95	63,76
average	4,45	3,19
mínimum	2,19	1,09
máximum	8,31	4,97

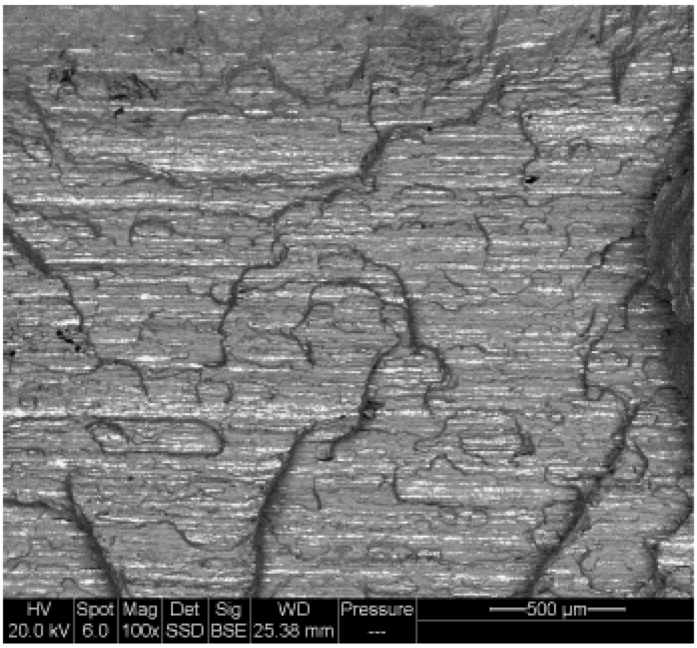

Figure 4. Sample A – image by backscattering electrons – clear points are Pb non metallic inclusions

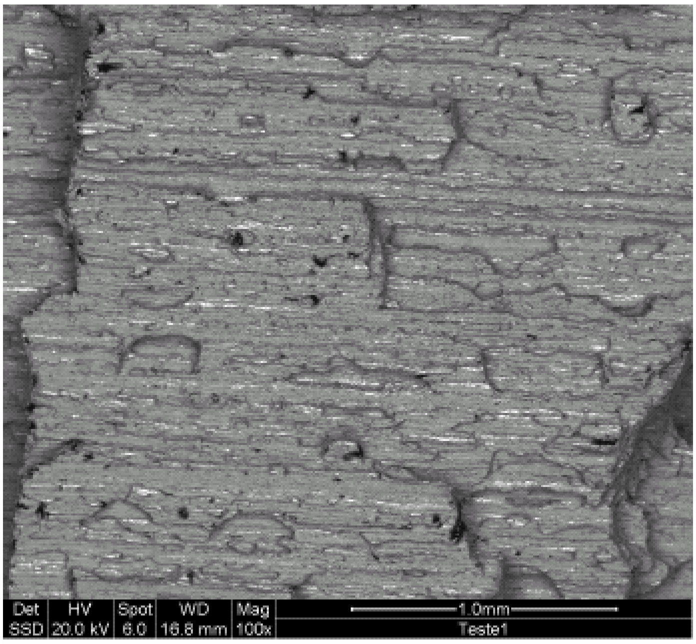

Figure 5. Sample C – image by backscattering electrons – clear points are Pb non metallic inclusions

2.7. Failure analysis:

In the failures analysis, we used MEV FEI Quanta 200. The national samples A and B, present cracks by fatigue that has yours begin in the region of the chamber of high pressure, where is executed ECM(electrolytic chemical manufacturing). The begin of the cracks happened starting from Lead inclusions.

In the imported samples C and D, the break mechanism is by fatigue, the sample C has begin inside of the chamber of high pressure where the operation of ECM is executed and where is verified the irregular removal of material through this operation. The sample D has begun of the crack in the region of the hole of high pressure, below the chamber, where the ECM operation is executed. In the two imported samples, the cracks have begin starting from pitting's that are present in every diameter of the hole.

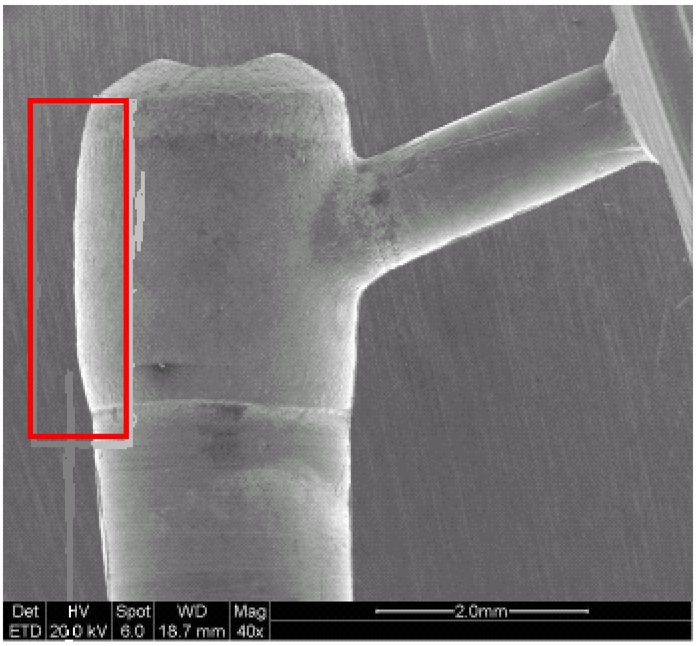

Figure 6. Sample A – Visualization of the failure - material removal in the chamber of high pressure

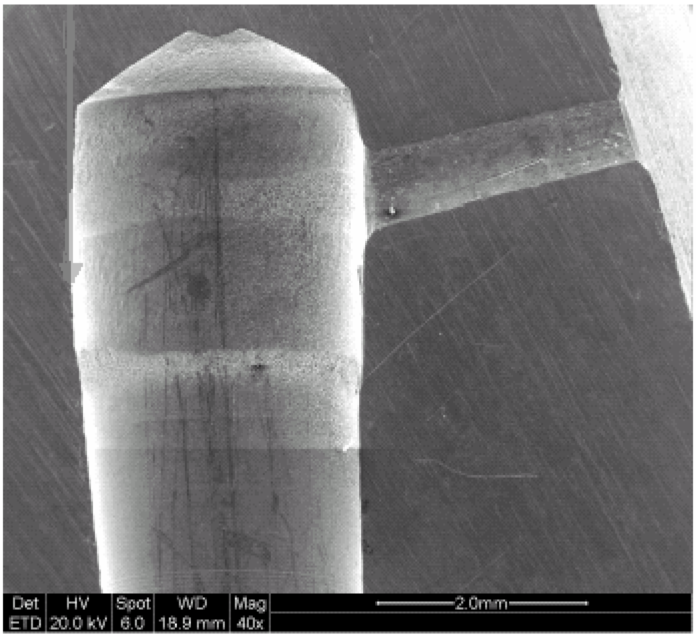

Figure 7. Sample C – Visualization of failure

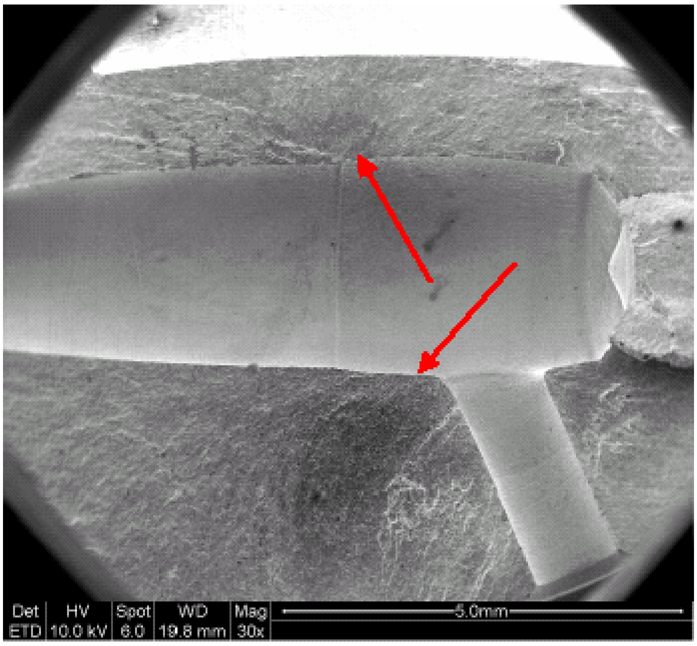

Figure 8.Sample A – begin starting of the cracks (arrows)

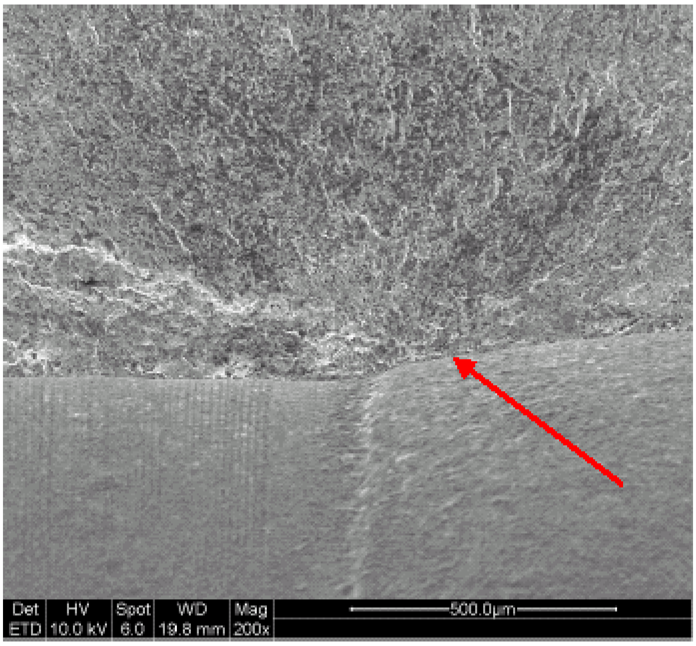

Figure 8. Sample A- detail figure 7, crack by fatigue beginning in the high pressure chamber

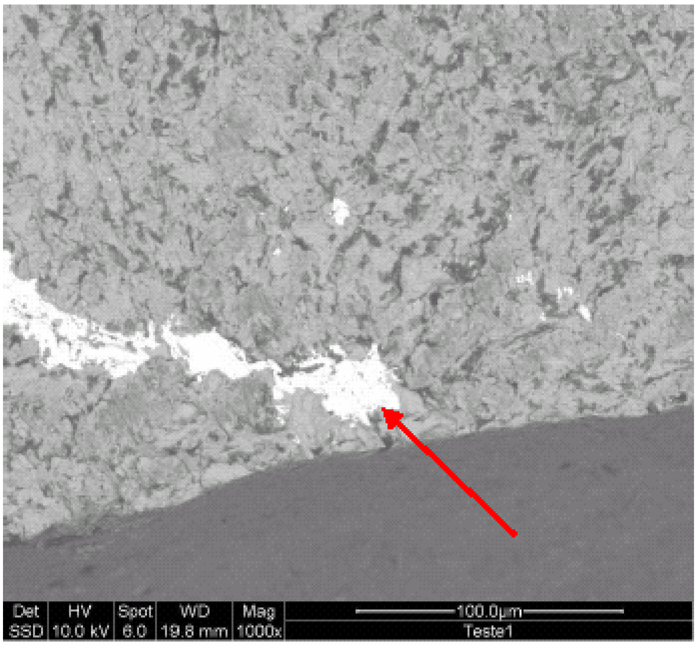

Figure 9. Detail figure 8, the begin crack in the Pb non metallic inclusion (arrow)

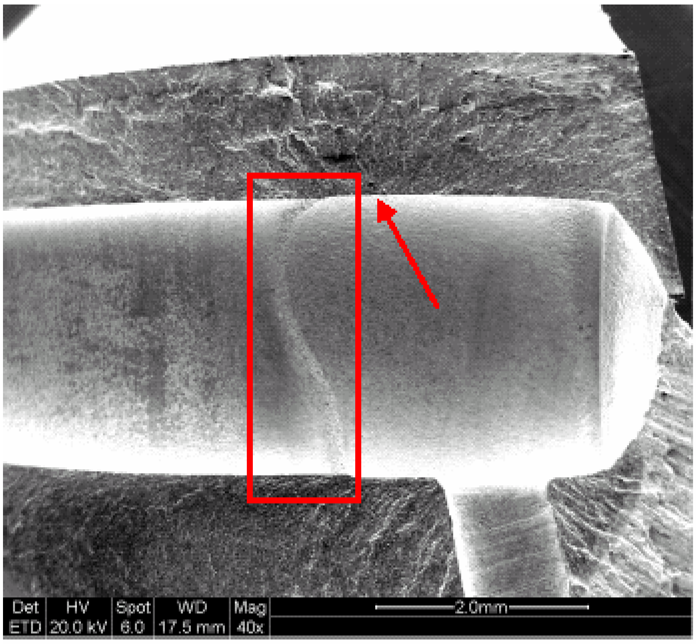

Figure 10. Sample C - begin starting of the cracks (arrow), and wrong ECM result.

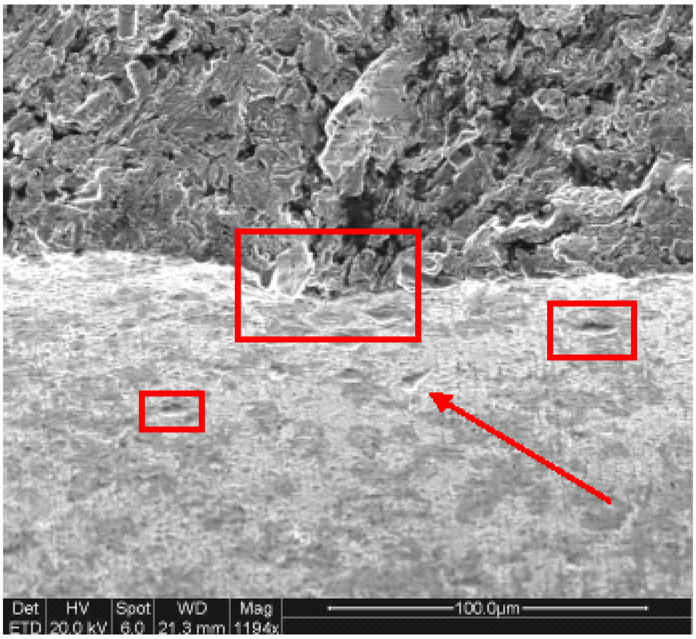

Figure 11. Detail figure 10, begin of the crack (arrow) and pitting's

2.8. Conclusions:

2.8.1. About hardness:

The national samples analyzed presented the Brinell and Vickers Hardness greater than imported samples.

2.8.2. About of the non metallic inclusions:

The level of Lead inclusions in busy area in mm2 of the national samples is 39, 5% larger in relationship the imported samples. The distribution of the inclusions in the imported samples is more homogeneous, while in the national samples the inclusions present several concentration areas. The specification of inclusions in the norm of the raw material, it allows fine inclusions of Lead when distributed homogeneously about the section, Lead inclusions in bands or concentrated, they are not allowed.

2.8.3. About of the chemical composition:

The chemical content of the, Si S, Pb, Al, Mo, Ni and Cu, they presented significant difference among the national samples and imported samples.

The facilitative elements of the machining are S and Pb, and imported raw material samples present chemical contents of these elements 122% larger than the national samples. The Sulfur combines with Manganese and with the Iron forming the manganese sulfite and iron sulfite. The Sulfur has larger likeness with the Manganese than with the Iron in the solid solution, of the both sulfites there will always be predominance of the manganese sulfite when the chemical content of Manganese of the league be considered loud. The presence of manganese sulfite increases the forgeable of the steel, with consequent it gets better in the machinable. The Lead chemical content in the national sample, as it was already commented on previously is larger than in the imported sample, as well as it concentrated distribution and no homogeneous as in the imported sample.

The elements Cu, Ni, Si and Mo, they tend to hinder the machinable of the material, and the chemical content found in the national samples of Cu and Si was of 1200% and 44% larger in relation to the chemical contents found in the imported samples.

The Copper in small quantities (smaller than 1,5%) is dissolved in the ferrite increasing the resistance the atmospheric corrosion and the hardenability and machinable.

The Silicon presents characteristic same. The elements Ni and Mo aid in the hardenability and consequently they hinder the machinable.

The related facts previously indicate a tendency for the difficulty of machinable of the component. With these factors it is necessary a reappraisal of the parameters of the machinable process as: cut speed, progress of the tool, number of passes, rotation, effect and efficiency of the cooling.

Because the same can provoke tension residual stress that associated the stress concentrators, as inclusions and pittings, abbreviate the useful life of the sample

3. ACKNOWLEDGEMENTS

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