Scrap Reduction of Railroader Axle on Carajás Railroad

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Abstract

During the wheelset maintenance process, the number of the axles is reduced by scrapping which makes it difficult to comply with the wagon maintenance plan. To re–establish the number of wheelsets, it is necessary to purchase new axles at a cost U$ 2,386.36 per unit. The average number of scrap axles is 26.44 units or 5.4% per month, which raises the maintenance costs of the wagons. Thus, the problem was identified, the goal was defined based on history, and it was stratified with tree diagram, pareto, sequential graph, boxplot and histogram. From the tree diagram, we identified the components involved with the problem of the high scrap rate of axle 6.1/2x12 by groove in the sleeve. Then, the brainstorming session of the causes of the groove was elaborated, the causes were prioritized for study by correlation, q-square test, boxplot, histogram and soft flexion test. Then, the proven causes for treatment, elaboration and effective action plan were prioritized. The result was that, while 3,03% of the groove axes studied were scrapped up to 5.47 months, 35.43% of the tested axles (127 units) went through this period without groove. The expenditure avoided with the 127 axles of the sample was about U$ 223,810.98. The projected avoided expenditure 4 years (large scale application) is about U$ 1,562,583.81. The completion of the work was by the pilot test and serves as a basis for large-scale application of the solution in the fleet.

Keywords
Scrap, Axle, Groove, Railroad, Maintenance.

1. Introduction

The scrapping of wagon's axles is common in railroads and has a significantly high impact in the maintenance costs. Therefore, it is highly important to identify the root causes of this problem utilizing robust methodologies and the implementation of actions that are effective in their elimination. For that, we tackled this challenge using the 6 Sigma method, grounded on PDCA, understanding the whole process and data collection, using statistic soft, with chi square distribution, histogram, boxplot, normal probability, correlation (dispersion diagram), tree diagram, pareto chart, Ishikawa diagram, prioritization matrix, descriptive statistic and sequential chart.

2. Problem identification

The period studied was based between 2016 January to 2017 April with great occur of the axles scrap. See wheelset image in (Figure 1) compound per axle, wheel and bearing, where occur the scrap trouble.

To minimize the scrap, the objective was determined based on the historical analysis in the first quarter method, due in a few months the reach was below the goal by the gap method.

Gap method is (average + minimum) / 2 = (5.4+2.3)/2 = 3.85%.

Desire to decrease the average month percentage of scrap axles from 5.4% to the goal of 2.83%, first quartile, until 2018 April. The return of the project will be when the pattern conditions been applied on wheelset after project definitions.

The general target was defined to decrease average 26.44 axles/month on studied period between 2016 January to 2017 April to 13.85 axles/month on verified period between 2017 December to 2018 March. See chart in (Figure 1). The indicator is better to down.

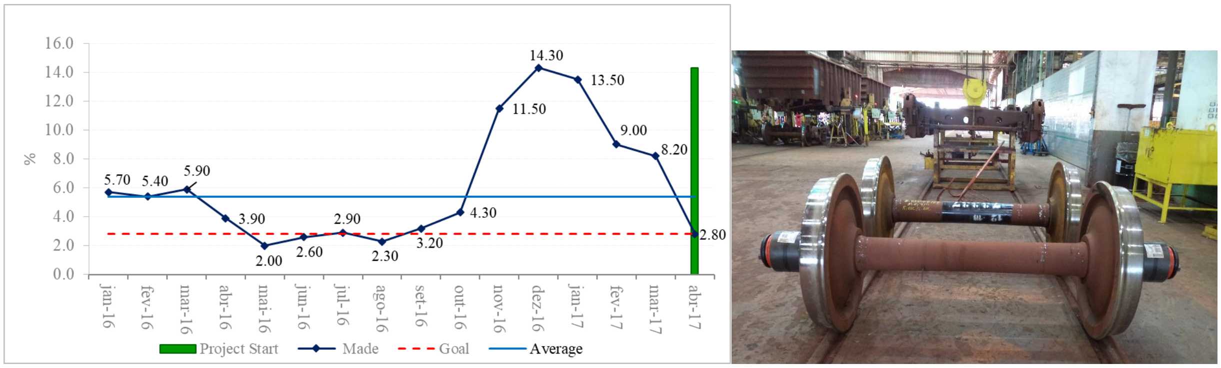


Figure 1. Scrap Index of Railway Axle and wheelset image.

3. Analyses of the phenomenon

3.1 Stratification problem plan

Phenomenon stratification analysis and focus definition was through the tree diagram, like seen in (Figure 2). The problem was stratified by axis and defect occurred. The data were collected in the workshop during the maintenance of the wheelset where the reasons for the axle scrap are pointed out.

Axle scrap

Axle 6.1/2x12 to cylindrical roller bearings		Axle 6.1/2x12 to Cartridge bearings		Axle 7 x 12 to Cartridge bearings		Axle 6 x 11 to Cartridge bearings		Axle 6 x 11 to cylindrical roller bearings	
Groove	221	Groove	151	Damaged radius	1	Bending	2	Bending	1
Bending	15	Bending	23			Groove	1		
Damaged radius	9	Accident	1						
Seat damaged	1	Indistinct defect	1						
Indistinct defect	1								

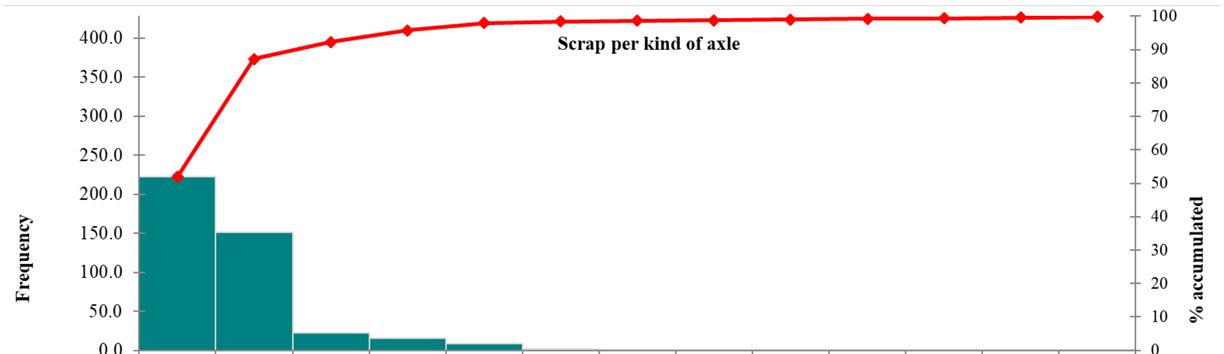
Figure 2. Tree diagram

3.2 Stratification problem

The groove develops on radius base on axle journal an unfavorable circumstance the operations, where a crack can occur. The axle with groove is classified as scrap and will be study focus, see (Figure 3).

Figure 3. Groove on journal

Axles to cylindrical roller bearing, represent 52.0% scrap. Axles for cartridge bearings, represent 35.0% scrap. The two, represent 87.0% of these axes of scrap with groove in the last 16 months, followed by the bending with 9.6%. The other defects complete 3.3%, see (Figure 4). Pareto diagram too was made conforming Trivellato at al. (2010).

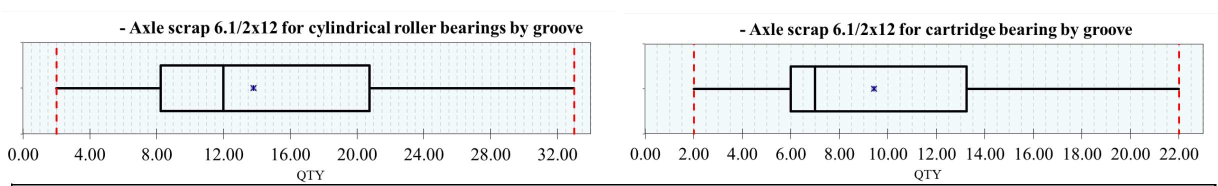


	6.1/2x12 Axle with groove	6.1/2x12 Cartridge axle with groove	6.1/2x12 Cartridge axle with bending	6.1/2x12 Axle with bending	6.1/2x12 axle with damaged radius	6 x 11 Cartridge axle with bending	accidented 6.1/2x12 Cartridge axle	6.1/2x12 Cartridge axle with indistinct defect	Axle 6.1/2x12 seat damaged	6.1/2x12 axle with indistinct defect	Cartridge axle 7 x 12 with damaged radius	Cartridge axle 6x11 with groove	6 x 11 axle with bending
Frequency	222.00	151.00	22.00	15.00	9.00	2.00	1.00	1	1	1	1	1	1
% accumulated	51.9	87.2	92.3	95.8	97.9	98.4	98.6	98.8	99.0	99.2	99.4	99.6	99.8

Figure 4. Scrap reasons

3.3 Analysis in the focus variation

In both asymmetric boxplot to the right, they show the highest percentages concentrated in the third/fourth quartile, indicating a tendency of the increase of scrap. Axes 6.1/2x12 to cartridge bearings, as shows standard deviation 6.36 have minus scrap than the 6.1/2x12 to cylindrical roller bearing, with deviation 8.35. See (Figure 5). Boxplot was made too like Santos at al. (2018).



Variable	Números of data	Average	Standard Deviation	Mínimum	first quartile	Medium	third quartile	Máximum
Axle scrap 6.1/2x12 for cylindrical roller bearings by groove	16	13.81	8.35	2.00	8.25	12.00	20.75	33.00
Axle scrap 6.1/2x12 for cartridge bearing by groove	16	9.44	6.36	2.00	6.00	7.00	13.25	22.00

Figure 5. Boxplot Axle scrap

3.4 Specific goal definition

Reduce by 2017 December 1.75% of the groove scrap on axles 6.1/2x12 for cylindrical roller bearings with the Gap method, due to the 1st quartile of 1.60% did not reach the general target of 2.83%.

Reduce by 2017 December 1.28% of the groove scrap on axles 6.1/2x12 for cartridge bearings with the Gap method, due to the 1st quartile of 0.98% did not reach the general target of 2.83%.

In other words, in the first quartile, the sum of 1.60 more 0.98 results in 2.58% below the target of 2.83%, thus the gap method adds 1.75% more 1.28% results in 3.03% reaching the general target of 2.83%.

4. Analyses of the process

The data were obtained in observations in the workshop during the arrival of the wheelsets for maintenance where there was the disassembly of their components and verified relative movements, thus accounted the data the manifestation of the groove and studied their relationships.

4.1 Detail process

From the tree of the components, it was given the signaling of those who are involved with the groove anomaly in the journal which is scraping the axes, observed in the workshop, see (Figure 6).

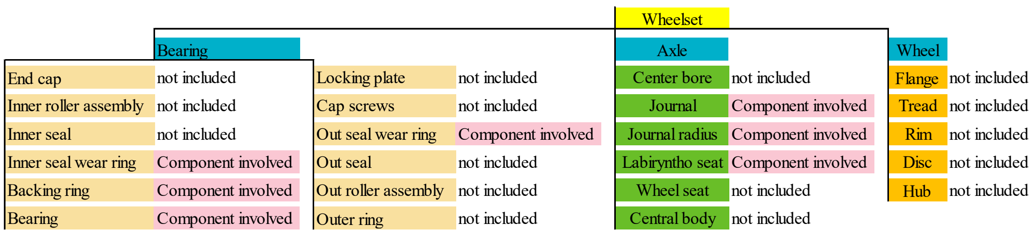


Figure 6. Tree of wheelset components signaling those involved with groove

4.2 Identification of causes

From the tree of components involved in the groove, it was elaborated cause and effect diagram with the participation of a workshop team, where each member expressed his opinion regarding the contribution of each component involved with the groove, seen in (Figure 7). It was made with base too in Camargo at al. (2011).

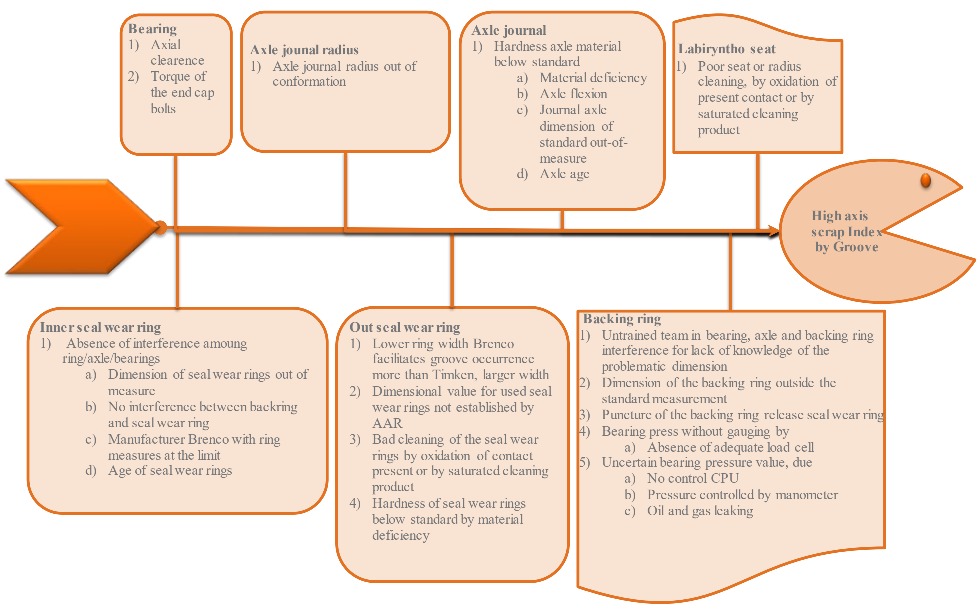


Figure 7. Cause and effect diagram

4.3 Priority causes

Starting from the brainstorm in the cause and effect diagram, the causes were ranked through the application of the prioritization matrix, raised 22 and prioritized 14 causes, with a score equal to or greater than 100, they are:

- Dimension of the backing ring outside the interference measure with axle;

- Dimension of the backing ring and seal wear ring outside the interference measure;
- Dimension of the seal wear ring outside the interference measure with axle;
- Dimension of the axle journal outside of the standard measure;
- Journal axle radius outside of the shape;
- Torque of the end gap bolts;
- Hardness of seal wear rings and baking ring below standard by material deficiency;
- Hardness journal axle material below standard by material deficiency;
- Axial bearing slack;
- Poor cleaning in labyrinth seat and axle radius, by contact oxidation or by saturated cleaning product;
- Narrow ring Brenco facilitates groove occurrence more than wide ring Timken;
- Untrained team in bearing, axle and backing ring interference for lack of knowledge of the problematic;
- Railroad axle flexion;
- Age of use of axles, seal wear ring and backing ring.

4.4 Testing and validation of causes

The flexion was tested using the resistance soft test and the point where the axis suffers greater load is exactly in the region of the local labyrinths where the flexion acts in greater emphasis. The base of the radius is a critical location for the rings. Therefore, it is concluded that flexion is a confirmed proven cause of scrap axle (Figure 8). Elastic modulus 200000 N/mm. Poison coefficient 0.3 N/A. Shear module 80000 N/mm. Specific mass 7900 Kg/m³. Tensile strength 746.1 N/mm³. Flow limit 370.9 N/mm. Thermic conductivity 0.2256 W/ (m. K). Specific Heat 1386 J/ (Kg. K)

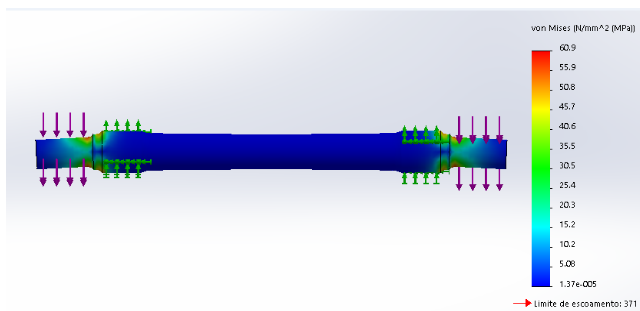


Figure 8. Axle test in resistance soft test

Bad cleaning of the labyrinth seat or radius on the axle by oxidation of present contact or by saturated cleaning product. There is a correlation between the rusty radius and journal. The groove is also caused by contact oxidation in the axle, no from cleaning, but from the absence of protection for corrosion. Like, P-value is 0.002 lower than 0.05 conclude there is association, seen in (Figure 9). Chi square distribution conforming Lane at al. (2018).

The correlation of the groove with the adjustment loose of the backing ring and seal wear ring and axle was confirmed, i.e. the dimension of the backing ring and seal wear ring loose the axle, being outside the interference measure. The P. Value 0.001 was less than 0.05 in (Figure 10), this correlation is a cause of the groove.

			Journal		
			Groove	No groove	Quantity
Rusty radius	Rusty	n	24	22	**46**
		%	52.17%	47.83%	100%
		E	29.21	16.79	46.00
	Machined Contact	n	16	1	**17**
		%	94.12%	5.88%	100%
		E	10.79	6.21	17.00
	Quantity	n	**40**	**23**	**63**
		%	**63.49%**	**36.51%**	100%

n : Observed Frequency; % : Percent in Line; E : Expected Frequency;

Chi Square by Pearson: **9.421**
p-Valor : **0.002**

Figure 9. Rusty radius and journal

			Axle		
			Groove	No groove	Quantity
Backing ring and seal wear ring	Holding	n	15	21	**36**
		%	41.67%	58.33%	100%
		E	20.67	15.33	36.00
	Loose	n	16	2	**18**
		%	88.89%	11.11%	100%
		E	10.33	7.67	18.00
	Quantity	n	**31**	**23**	**54**
		%	**57.41%**	**42.59%**	100%

n : Observed Frequency; % : Percent in Line; E : Expected Frequency;

Chi Square by Pearson: **10.944**
p-Valor : **0.001**

Figure 10. Adjustment backing ring, wear ring and axle

Dimension of seal wear rings outside the interference measurement with axle. Confirmed correlation between groove and seal wear ring measurement with axle journal dimension outside the interference for cylindrical roller bearing and cartridge axle. Thus, being the cause of groove on both axes. In (Figure 11) the variable X 3 means this result of interference P value is 2.5186e-07 and confirms the correlation.

SUMMARY OUTPUT

Regression Statistics		
Multiple R	0.8660634	There is correlation because it is above 0,7
R Square	0.7500658	75% of the groove can be explained by the variation of the three variables (couplings)
Adjusted R Square	0.7232871	
Standard Error	0.0068573	
Observations	32	

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	0.003951294	0.0013171	28.009824	1.40845E-08
Residual	28	0.001316636	4.702E-05		
Total	31	0.00526793			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	6.1941776	0.002161608	2865.5421	4.294E-78	6.189749777	6.1986055	6.18974978	6.19860548
X Variable 1	0.1261399	0.085118693	1.4819295	0.1495268	-0.04821784	0.3004976	-0.0482178	0.30049764
X Variable 2	0.2602003	0.176416834	1.4749174	0.1513914	-0.10117325	0.6215738	-0.1011732	0.62157376
X Variable 3	0.6045181	0.089606509	6.7463635	2.519E-07	0.420967467	0.7880687	0.42096747	0.78806869

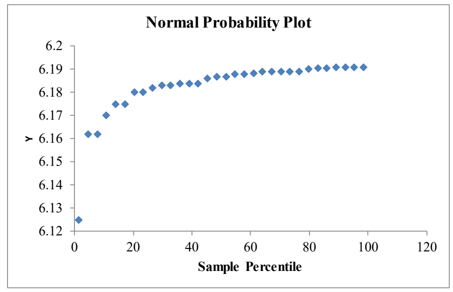


Figure 11. Normal curve, correlation between wear ring and axle

Dimension of the backing rings outside the interference measure with labyrinth seat. Confirmed correlation between backing ring measurement and labyrinth seat dimension out of interference to cylindrical roller bearing axle. Thus, being the cause of the groove on this axis. The result was Pearson`s correlation coefficient: 0.605 and P-value for the correlation test: 0.000. See (Figure 12). So, absence of interference between backing ring and labyrinth seat is proven cause of groove in cylindrical roller bearing axle.

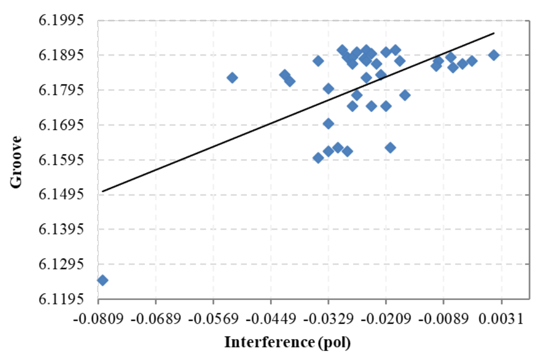
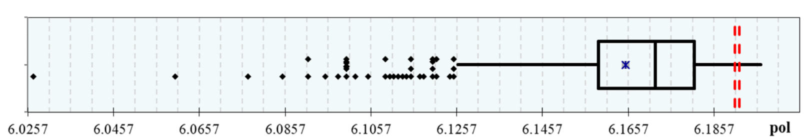


Figure 12. Correlation groove and interference between backing ring and labyrinth seat in the axle for roller bearing

Dimension of axle journal outside standard measurement. The boxplot is asymmetrical left, the minimum dimensional 6.1905" for the diameter of the journal radius located in the 4th quartile or below the standard, see (Figure 13). Radius base of the journal is proven cause, namely is the groove itself. Boxplot was made with base too in Schneider at al. (2014).



Variable	Nùmbers of data	Average	Standard Deviation	Minimum	first quartile	Medium	third quartile	Màximum
Groove	466	6.1650	0.0233	6.0270	6.1588	6.1720	6.1810	6.1966

Figure 13. Boxplot - Radius base diameter (groove)

4.5 Validation of causes

Causes for treatment after confirmed like causes of the groove in 6.1/2x12 axles journal diameter for cylindrical roller bearing and cartridge bearing:

- Railroad axle flexion;
- Dimension of the seal wear ring outside the interference measure with axle;
- Dimension of the backing ring outside the interference measure with axle;
- Dimension of the backing ring and seal wear ring outside the interference measure;
- Dimension of the axle journal outside the standard measurement in the radius base;
- Poor cleaning in the labyrinth seat, in the axle radius, by oxidation of contact or by saturated cleaning product.

5. Established action plan

The action plan must be established when the probable solutions are chosen by prioritization defined through the scoring range, conditioning each action to a deadline and one responsible for applying it or making it feasible, will be considered test actions.

5.1 Priority causes to be eliminated

After each confirmed cause for to be eliminated, solutions for prioritization were attributed. A score was applied in each of the impact items on the cause, complexity, cost and term, and a proportion applied in each of the four items, generates the final sum of each solution, prioritizing those whose score reached 100 or more points, see in Table 1.

Table 1. Prioritization of solutions for groove causes in 6.1/2x12 axis

	Priority weight	10	8	8	6	
Cause for eliminate	Solutions likely	Impact	Ease	Cost	Deadline	Quantity
Railroad axle flexion	Change of design of EFC's wheelset	5	1	1	1	72
Railroad axle flexion	Limiting transport load by EFC axis	5	1	1	3	84
Dimension of the seal wear ring outside the interference measure with axle	Creating the color code for implementing the seal wear ring control within the standard measurement	5	5	5	5	160
Dimension of the seal wear ring outside the interference measure with axle	Application of new seal wear rings replacing those no interference.	5	5	3	3	132
Dimension of the backing ring outside the interference measure with axle	Creating the color code for implementing the backing ring control within the standard measurement	5	5	5	5	160
Dimension of the backing ring outside the interference measure with axle	Application of Timken Surefit backing rings on axles journal 6.1/2x12 for cylinder roller bearings	5	5	3	3	132
Dimension of the backing ring and seal wear ring outside the interference measure	Creation of the color code to implement the control of backing ring and seal wear rings within the standard measure	5	5	5	5	160
Dimension of the backing ring and seal wear ring outside the interference measure	Application of new fitted backing rings and new seal wear ring to replace those no interference.	5	5	3	3	132
Dimension of the axle journal outside the standard measurement in the radius base	Application of new, Timken Surefit, fitted backing rings and seal wear ring replacing those no interference.	5	5	3	3	132
Poor cleaning in labyrinth seat and axle radius, by contact oxidation or by saturated cleaning	Apply antioxidant tectil protection in the bearing installation	3	3	3	1	84
Poor cleaning in labyrinth seat and axle radius, by contact oxidation or by saturated cleaning	Remove rusty radius by sanding	3	3	3	1	84

5.2 5W2H of experimental test plan

An experimental action plan was elaborated for the solutions that were defined, containing causes, how to solve and how many. The fields of who when and where in this article are not considered, however, are existing and defined fields in practice, as shown in table 2.

Table 2. 5W2H experimental action plan establishment

Cause for eliminate	Solutions likely	What?	Why?	How?	How many?
Dimension of the seal wear ring outside the interference measure with axle	Creating the color code for implementing the seal wear ring control within the standard.	Create coding	Avoid loose rings	Developing code	Low
Dimension of the seal wear ring outside the interference measure with axle	Application of new seal wear rings replacing those no interference.	Budget predict	Avoid loose rings	Raising cost and informing	Low
Dimension of the backing ring outside the interference measure with axle	Creating the color code for implementing the backing ring control within the standard.	Create coding	Avoid loose rings	Developing code	Low
Dimension of the backing ring outside the interference measure with axle	Application of Timken Surefit on axles journal 6.1/2x12 for cylinder roller bearings	Budget predict	Avoid loose between rings	Raising cost and informing	Low
Dimension of the backing ring and seal wear ring outside the interference measure	Creation of the color code to implement the control of backing ring and seal wear rings.	Create coding	Avoid loose between rings	Developing code	Low
Dimension of the backing ring and seal wear ring outside the interference measure	Application of new, fitted backing rings and seal wear ring to replace those no interfere.	Budget predict	Avoid loose between rings	Raising cost and informing	Low
Dimension of the axle journal outside the standard measurement in the radius base	Application of new Timken surefit, fitted backing rings and seal wear ring replacing those no interference.	Create budget	Avoid loose rings	The large-scale rings budget in PDMF	Low
Dimension of the axle journal outside the standard measurement in the radius base	Application of new, fitted backing rings and seal wear ring replacing those no interfere.	Teaching coding	Avoid loose rings	Training on the job	Low

6. Action plan implant

Through the color code, combinations of inspected rings, new rings and test rings were applied in 170 wheelsets, after installed in wagons was monitored between three and six months.

6.1 Realization of experimental test plan

The diameters of the backing rings are measured and assigned a color classising them, according to the range of the measurement from 1 to 5 below:
1 – Green, Seat is less than or equal to 7.528 "and coupling less than or equal to 6.811";
2 – Blue, Seat is less than or equal to 7.528 "and coupling greater than 6,811" up to 6.818 “;
3 – Yellow, Seat is greater than 7.528 "up to 7.533" and coupling less than or equal to 6.811 ";
4 – Red, Seat is greater than 7.528 "up to 7.533" and coupling greater than 6.811 "up to 6.818“;
5 – New, black Seat is less than or equal to 7.528 "and coupling less than or equal to 6.811“.

The diameters of the seal wear rings are measured and assigned a color classising them, according to the range of the measurement from 1 to 5 below:
1 – Green, Outer diameter greater than or equal to 6.812“. Inner diameter less than or equal to 6.1885“;
2 – Blue, Outer diameter less than 6.812 "inner diameter less than or equal to 6.1885“;
3 – Yellow, Outer diameter greater than or equal to 6.812“. Inner diameter greater than 6.1885 "up to 6.193“;
4 – Red, Outer diameter less than 6.812" Inner diameter greater than 6.1885 "up to 6.193“;
5 – New, Outer diameter greater than or equal to 6.812“. Inner diameter less than or equal to 6.1885".

After the rings sorted and separated by colors, pairs of rings are formed following the color combinations from 1 to 9 below. The rings are fixed to each other by pressing and with a steel bar are touched, aiming to hear the sound produced from the touch, if the sound is shrill the assembly is good, if the sound is muffled are disassembled for other pairs.

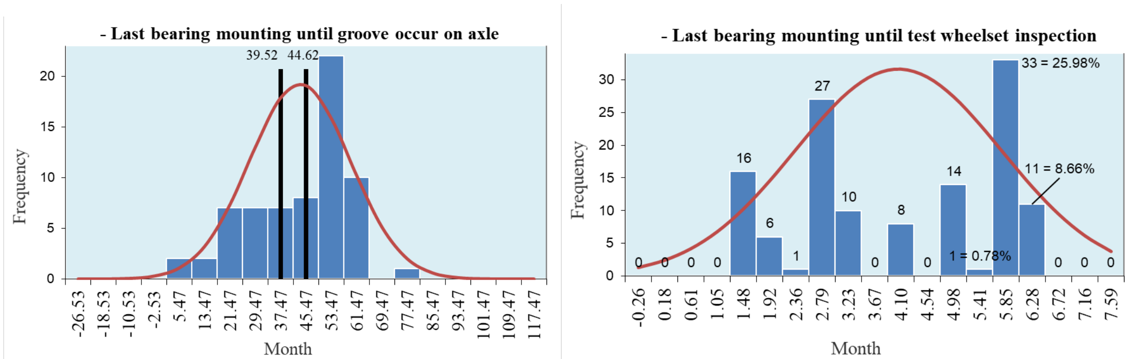
Combinations from 1 to 9 below allow pairs of rings to stand firmly between each other and axle and are installed:
1 – Green Backing Ring – Green Seal Wear Ring; 2 – Green Backing Ring – Blue Seal Wear Ring;
3 – Blue Backing Ring – Green Seal Wear Ring; 4 – Yellow Backing Ring – Blue Seal Wear Ring;

5 – Black New Backing ring – Blue Seal Wear Ring; 6 – Blue Backing Ring – Black New Seal Wear Ring; 7 – Green Backing Ring – Black New Seal Wear Ring; 8 – Yellow Backing Ring – Black New Seal Wear Ring; 9 – Red Backing Ring – Black New Seal Wear Ring.

6.2 Result the experimental test plan

At the beginning the scrapping of up to 5,47 months 3.03% of the groove axes, had an average plan of 39.52 months and median of 44.62 months (Figure 14 A).

The experimental test checked 127 axes and none of them released a ring, i.e. 74.70% of tested axles there was no occurrence of groove, and 35.43% reached 5.47 months without groove (Figure 14 B). Histogram too was made like Trivellato at al. (2010).



Variable	Númbers of data	Average	Standard Deviation	Minimum	first quartile	Medium	third quartile	Máximum
Last bearing mounting until groove occur on axle	66	39.52	15.86	1.47	28.04	44.62	51.34	76.60
Last bearing mounting until test wheelset inspection	127	3.84	1.71	1.27	2.47	3.67	5.77	6.07

Figure 14. Last bearing mounting until groove occur (A) X Last bearing mounting until test wheelset inspection (B)

6.3 Plan to large escale

Action Plan 5W2H for the implementation of large scale resolutions. The fields of who when and where in this article are not considered, however, are existing and defined fields in practice, as shown in table 3.

Table 3. 5W2H action plan for large scale

Cause for eliminate	Solutions to be implemented	What?	Why?	How?	How many?
Dimension of the backing ring and seal wear ring outside the interference measure	Application of new fitted backing rings and new seal wear ring to replace those that no interfere.	Start of inserting new rings in the process	Avoid loose the rings in cartridge bearing and cylindrical roller bearings.	Providing in bearing maintenance	Fitted backing ring 85.61 and seal wear ring 231.06 parts (U$ 25,242.85/month)
Dimension of the backing ring outside the interference measure with axle	Application of Timken Surefit backing rings on axles journal 6.1/2x12 for cylindrical roller bearings	Start of inserting the new Timken Surefit rings in the process	Avoid loose of rings in cylindrical roller bearings axle	Providing wheelset with rings classified in bearings	110.17 parts/month (U$ 9,094.94)
Dimension of the backing ring and seal wear ring outside the interference measure	Creation of the color code to implement the control of rings within the standard measure	Apply encoding	To avoid loose rings in cartridge bearings and cylindrical roller bearings.	Officializing code to the supervisors of the workshops	without cost
Dimension of the seal wear ring outside the interference measure with axle	Application of backing ring and seal wear rings in the approved configurations.	Training application coding of rings with the assembly and bearing maintenance team.	To avoid loose rings in cartridge bearings and cylindrical roller bearings.	On the job training	without cost
Dimension of the seal wear ring outside the interference measure with axle	Application of backing ring and seal wear rings in the approved configurations.	Create or revise maintenance procedures for wheelsets, bearings or rings.	To avoid loose rings in cartridge bearings and cylindrical roller bearings.	Updating document	without cost

7. Verification of results

7.1 Check target range specifies

Due to the high answer time for the test, the results were not measured by the specific objectives previously defined. After the 170 axes tested, 127 were verified and found without a loose ring (without groove), representing 74.70% of satisfactory answer. There were also disassembled 20 bearings, checked journals which did not show groove or progression of the same, see (Figure 15). The data of this disassembly show correlation between axis and ring interference, as seen in (Figure 16), thus, there was a re-definition of the targets due to the answer time and redirection of the Master Plan of Railway Maintenance (PDMF) for large scale.

Figure 15. Adjustment between rings and axle without groove progression

			Interference		
			Adjusted	No adjusted	Quantity
Axle / Rings	Labirynto seat / Backing	n	15	5	**20**
		%	75.00%	25.00%	100%
		E	11.50	8.50	20.00
	Axle Journal / Seal	n	8	12	**20**
		%	40.00%	60.00%	100%
		E	11.50	8.50	20.00
	Quantity	**n**	**23**	**17**	**40**
		%	**57.50%**	**42.50%**	100%

n : Observed Frequency; % : Percent in Line; E : Expected Frequency;

Chi Square by Pearson:	**5.013**
p-Valor :	**0.025**

Figure 16. Chi square distribution, to adjustment rings and axle

7.2 Project results

The goal was reached following 127 axles in test and did not have none loose rings, after field inspection, indicating axles without groove or progression, like seen in (Figure 17).

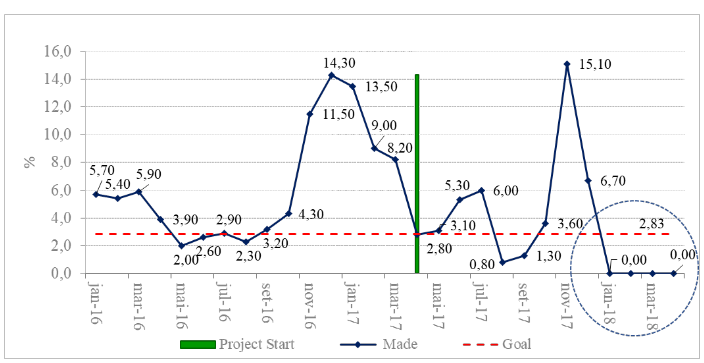


Figure 17. Scrap Index to Railroad axle EFC

7.3 Real financial gain designed

The qualitative gains were, the operational safety and reliability growth due to axes without groove.

Quantitative real gains:
- The 35.43% of the axes tested did not show groove up to 5.47 months;
- The 8.66% of the axes tested, worked more than 6 months without presenting groove;
- The 127 inspected axles from 170 tested (74.70%) none presented groove;
- Expending avoided by axle lost U$ 223,810.98.

Quantitative loss reduction by real designed gains. See colors lines in Figure 23.
If nothing is done the axle loss in 5 years would be U$4,258,195.12 see red line. To correct the error, the expense with new rings and axes to replace those that are not normal in 4 years would be U$2,695,611.32 see line green. Thus, the reduction in 4 years would be U$1,562,583.80 by subtracting green line to red line.
The investment in 4 years with new rings would be U$1,358,173.30 after, none more would be applied as investment, see blue line. Correcting the problem, the annually expense avoided with axle scrap would be U$953,660.56. See last value to red line in Figure 18.

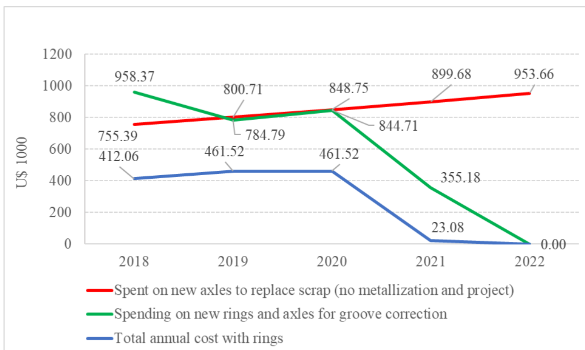


Figure 18. Total project cost with axle application against financial reduction

8. Patterning and maintenance to results

8.1 Training in the Process technical patterning

The color code process patterning was created to controlling rings off measurement, to admit only the rings that dimensional contact with axle to occur. The rings are classified in measurement band for color. The color code should occur like written in sub-heading (5.1 Realization of experimental test plan). The team was trained in this standard.

The backing ring diameter for axle seat greater than or equal to 7.534 inches are positioned in scrap location on inspection bench. The backing ring diameter to attach to the wear ring greater than or equal to 6.819 inches, are also positioned in scrap demarcation. For others measurement, sort the ring by color.

The wear ring inner diameter for journal greater than 6.193 inches are positioned in scrap location on inspection bench. Outer diameter for coupling to the backing ring greater than or equal to 6.812 inches, sort the ring by color.

General state of wear rings and backing ring, broken, cracked, bent, with deformation or punctures above 12 holes which do not allow more coupling, are positioned in scrap location on inspection bench.

8.2 Action plan in case of deviation

The table 4 shows the Out of Control Action Plan (OCAP). The fields of who, when and where in this article are not considered, however, are existing and defined fields in practice.

Table 4. 5W2H action plan in case of deviation

What?	Why?	How?	How much?
Stop at the insertion of the new rings in the process	Avoid discontinuity in the rings supply	Following Master Plan of Railway Maintenance (PDMF) providing rings in the maintenance.	Fitted backing rings 85.61 parts/month Surefit backing ring 110.17 parts/month Seal wear rings 231.06 parts/month
Limiting features for applying rings	To avoid discontinuity in the rings supply	Seeking resources with economic management	Fitted backing rings U$ 25,242.85/month Surefit backing rings U$ 9,094.94/month
Stop in the application of the ring selection coding.	To avoid loose ring in cartridge bearing and roller bearing.	Communication to bearings maintenance team the continuity	no cost
Untrained young employee in the process	To avoid loose ring in cartridge bearing and roller bearing	Training on the job the selection of all rings according to color coding.	no cost

9. Conclusion

The axis flexion is the largest responsible for the generation of groove, but due to its resolution in changing the design of the axle, it becomes something very expensive, then remains to control the dimension of the wear rings and backing ring to allow interference between them and the axis, eliminating the contact wear that originates the groove. Thus, maintaining interferences between these elements will be the way to avoid groove on axle.

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