Pantograph wear assesment in overhead conductor rail systems

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PANTOGRAPH WEAR ASSESMENT IN OVERHEAD CONDUCTOR RAIL SYSTEMS

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Abstract

Wear is the phenomenon that determines the lifetime of the collector strips. Since wear is an inevitable effect on pantograph-catenary systems, it is necessary to determine optimal operating conditions that can mitigate its effects. In this study we have performed a simulation model of the pantograph-overhead conductor rail system which allows the evaluation of the dynamic conditions of the system through the contact force. With these results we have made an evaluation of the quality of current collection, a calculation of the pantograph wear and a definition of the optimal operation conditions of the pantograph-overhead conductor rail system.

1. INTRODUCTION

Wear is the phenomenon that determines the lifetime of the collector strips, which establish the necessary contact for driving power from the catenary to the pantograph in railway vehicles. Since wear is an inevitable effect on pantograph-catenary systems, it is necessary to determine optimal operating conditions that can mitigate its effects.

The objective of study is to carry out a dynamic analysis of the system pantograph-overhead conductor rail, in order to study the conditions that allow a correct quality of current collection system and within these, which are those that maximize the life of collector strips, due to a lower wear.

This work has been developed within the Research Centre on Railway Technologies (CITEF). This Centre has an experience of a decade in dynamic simulation of pantograph-catenary systems [1-4].

2. DYNAMIC ANALYSIS. QUALITY ASSESSMENT OF CURRENT COLLECTION

It has been employed a model of the pantograph-overhead conductor rail system that combines simulation techniques of multibody systems with calculation by finite element, to consider the flexibility of the overhead conductor rail.

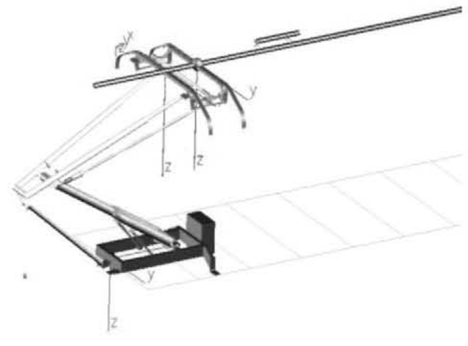


Figure 1. Model of the pantograph-overhead conductor rail system

In this model the main parameters of the system analyzed have been taken into account, carrying out variations of these to identify their influence, both in the quality of current collection as in the wear of the pantograph. These parameters are: distance between supports (8 and 10 m), stagger type (sine or linear), static force (between 50 and 200N), speed (between 50 and 150 km/h) and pantograph type (it has been modeling two types, corresponding to a metropolitan train and a suburban train).

The quality of current collection has been assessed in accordance with the criterion of the current standards through the contact force obtained in the simulations. It has been used statistical criterion as well as the percentage of take-offs.

- Statistical criterion: Taking into account the statistical distribution of values of the contact force, will define the next quotient is defined:

$$J_c = \frac{3\sigma_F}{F_m}$$

where σ_F is the standard deviation of the contact force, and F_m is that force media. For values below unity the quality of current collection will be guaranteed.

- Calculation of the percentage of electric arcs: This method determines the proportion of take-offs by calculating the term:

$$NQ = \frac{\sum t_{arco}}{t_{total}} x\ 100$$

which, for values less than the 0.14%, will ensure correct capturing quality.

Both the statistical parameter of the contact force as the percentage of take-offs are plotted against the static force and velocity, for each pantograph model and distances between supports (8 and 10m).

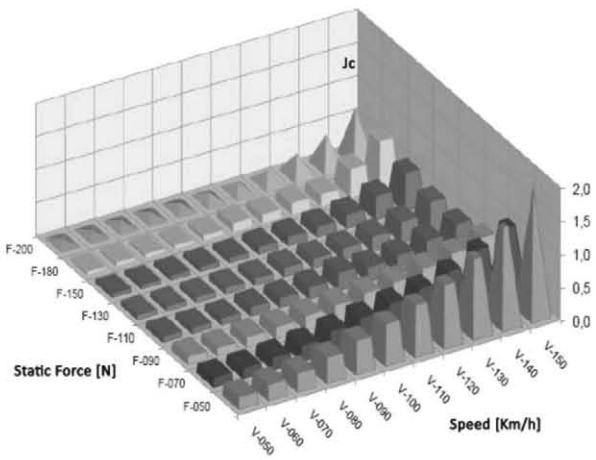
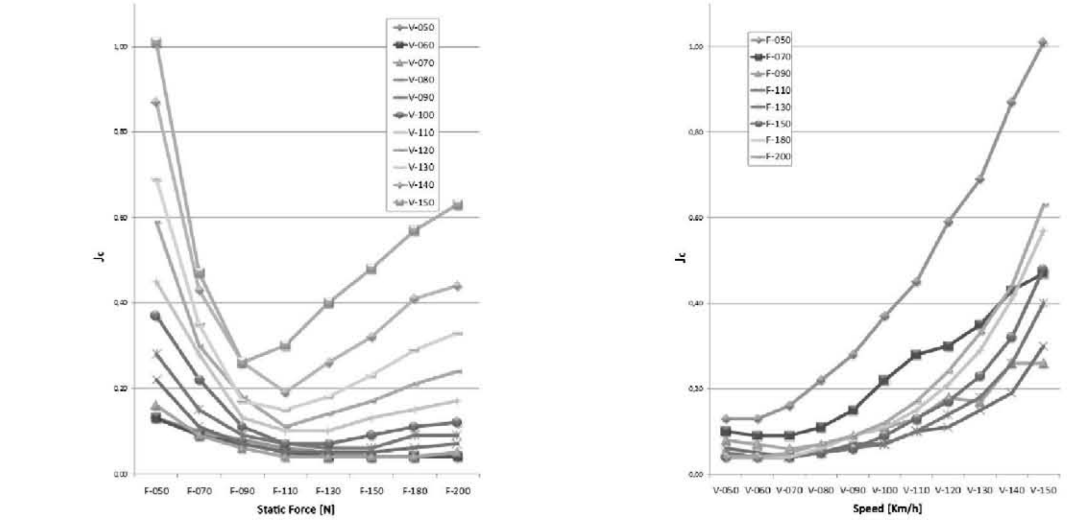


Figure 2. Statistical quotient (Jc) against the static force and velocity

These results have led to the conclusion that an increase in velocity implies an increase in the values of Jc and NQ, and therefore a lower quality of current collection (Figura 3a). On the other hand, the variation of static force has shown minimal values of Jc and NQ, and therefore, optimal conditions of operation of the system for a particular value of static force (Figura 3b).



a) Against speed. Constant static force *b) Against static force. Constant speed*

Figure 3. Statistical quotient (Jc)

The results of the simulations have revealed the conditions that lead to a better quality of current collection, as well as reject those cases with some unacceptable conditions. These results have been a previous filter. Only conditions which satisfy both criteria have been object of study of the wear produced. The following table summarizes the cases that meet the statistical criterion (E) or the percentage of take-offs (A), for each pantograph model (A o B), distance between supports, static force and speed.

Figure 4. Quality assessment of current collection

3. WEAR MODEL

In order to model pantograph wear is necessary to use an equation that include the contribution to the rate of wear both of the contact force, electric current and the appearance of electric arcs, but at the same time taking into consideration the influence that each of these phenomena performs on each other [5][6]. Thus, not considering the contribution by arches that have been removed in the preceding paragraph, the next equation has been used:

$$A = \frac{k_F}{(i+i_0)^{\frac{1}{n}}} F_c V + \frac{k_i}{\sqrt{F_c}} i^2$$

Where the k_F, k_i and n constants are known for the bibliography, and the other data, contact force (Fc), sliding velocity (V) and electric current (i) are calculated through the results from dynamic simulations and the resolution of the equivalent electrical circuit of the railway system. This model has allowed to obtain the curve of pantograph wear (wear depth for each point of the collector strip width), by the addition of the contributions mechanical and electrical.

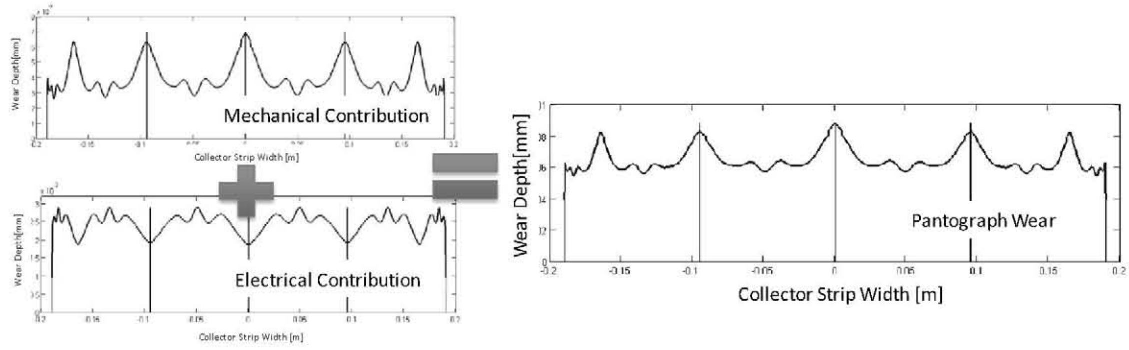
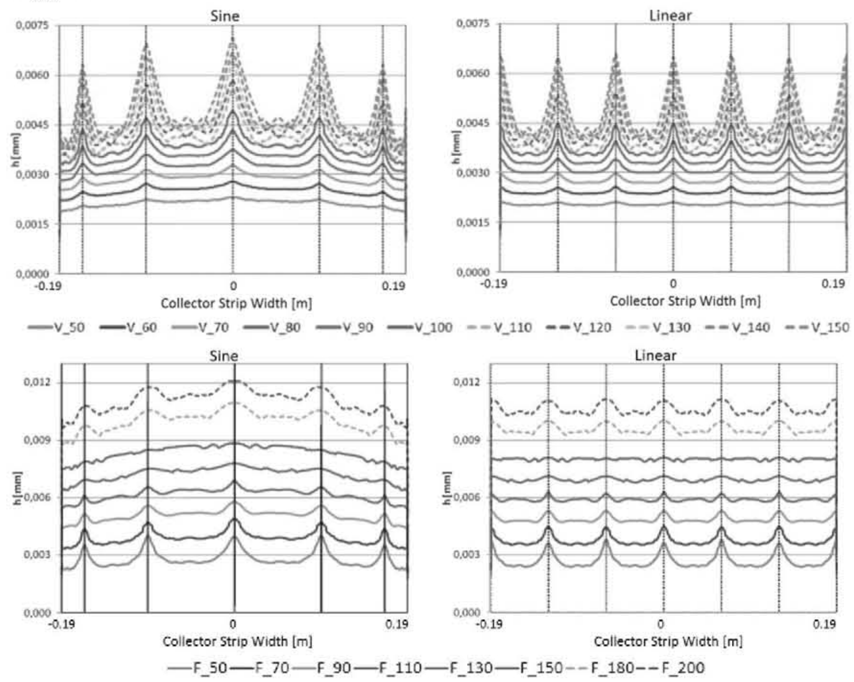


Figure 5. Pantograph wear

The results (Figure 6) obtained for the mechanical contribution show as the peak values of wear are obtained when the pantograph pasat the points of passage through the supports. Besides increasing the speed or the static force leads to a higher mechanical wear. Mechanical wear is less with the linear stagger.



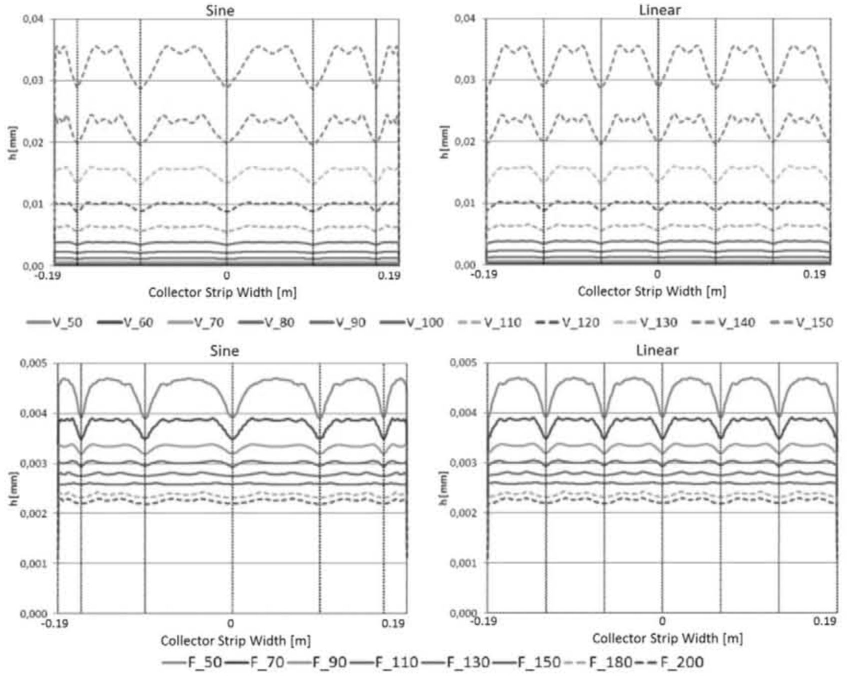
a) Constant static force

b) Constant speed

Figure 6. Pantograph wear depth (h) - Mechanical contribution

In regards the electric contribution can be seen as, unlike the mechanical contribution, the points of passage through the supports present valleys in the pantograph wear. Thus, according to the preponderance of any contribution will be peaks or valleys in the total wear at the points of passage through the supports.

On the other hand, as for mechanical wear, increasing the velocity leads to higher electrical wear. However, the static force behavior presents a contrast to the previous case. An increase in the static force produces a decrease in wear due to electrical phenomena. The stagger type is not a relevant factor for the electrical contribution to wear.

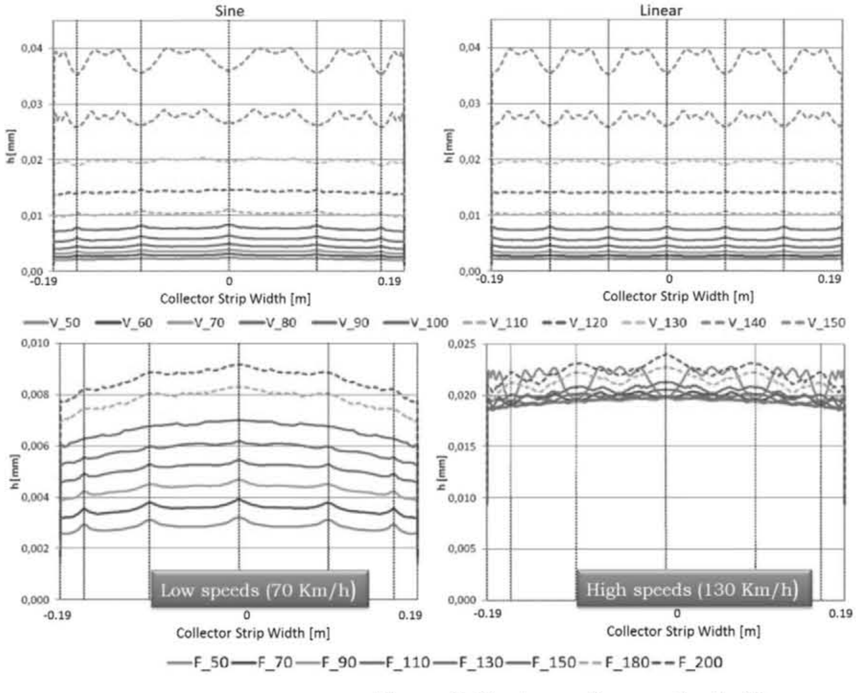


a) Constant static force

b) Constant speed

Figure 7. Pantograph wear depth (h) - Electrical contribution

Finally, the sum of the two contributions mechanical and electrical gives total wear. The increase in speed increases both the electrical wear as the mechanical wear, and therefore also total wear. However, the effects of static force for mechanical and electrical contributions are opposite and depend on the speed. Thus, at low speeds an increase of static force leads to a greater total wear, while at high speeds the effect is not predictable in principle. The linear stagger has a slightly smaller wear than the sine due to its effect on the mechanical contribution.



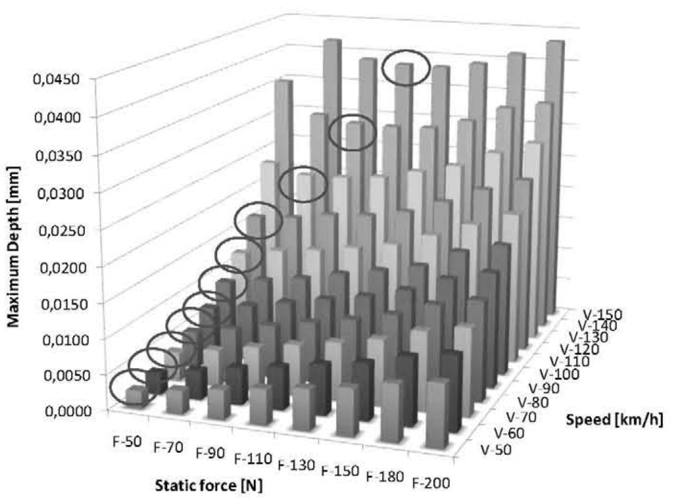
a) Constant static force

b) Constant speed

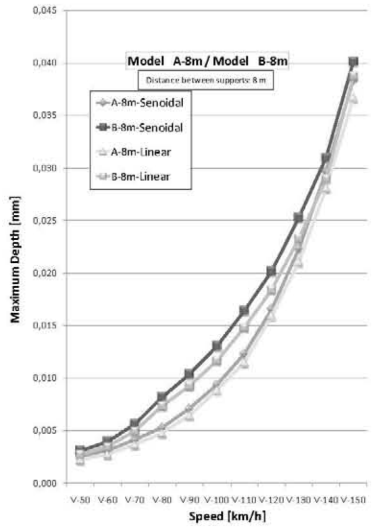
Figure 8. Pantograph wear depth (h)

4. CALCULATION OF THE OPTIMAL OPERATING CONDITIONS. USEFUL LIFE OF THE PANTOGRAPH

Lifetime of the pantograph has been estimated using maximum wear of the contact strip. Thus, maximum useful life corresponds to the case with the smallest value in the maximum depth of wear. From this result have been determined the optimum conditions of operation of the pantograph-overhead conductor rail system, which are those that define the case that leads minimum value of the maximum depth of wear. For example, for each speed of movement there an optimum static force that provides minimal wear, see Figure 2.a. Results obtained for the different analyzed scenarios have been compared (type of pantograph, distance between supports, stagger type, etc., see Figure 2.b.).



a)Maximum depth wear against speed and static force

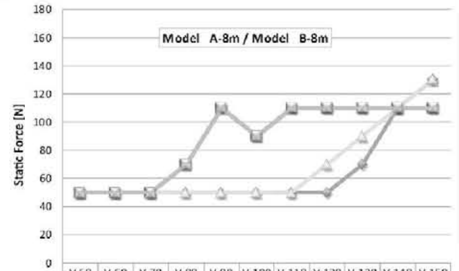


b) Maximum depth wear against speed (Distance between supports 8m)

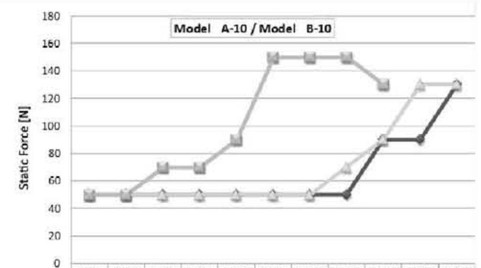
Figure 9. Optimal operation conditions

The best operating conditions from the point of view of wear are obtained for the linear stagger, the distance between supports of 10 m and the model of pantograph A.

Representing the pairs of speed and static force values that lead to the maximum useful life of the pantograph we have obtained maps of optimum operation conditions. These diagrams will be very useful when selecting the conditions of operation of the system pantograph-overhead conductor rail.



	V-50	V-60	V-70	V-80	V-90	V-100	V-110	V-120	V-130	V-140	V-150
A-8m-S	50	50	50	50	50	50	50	50	70	110	130
B-8m-S	50	50	50	70	110	90	110	110	110	110	110
A-8m-L	50	50	50	50	50	50	50	70	90	110	130
B-8m-L	50	50	50	70	110	90	110	110	110	110	110



	V-50	V-60	V-70	V-80	V-90	V-100	V-110	V-120	V-130	V-140	V-150
A-10m-S	50	50	50	50	50	50	50	50	90	90	130
B-10m-S	50	50	70	70	90	150	150	150	130		
A-10m-L	50	50	50	50	50	50	50	70	90	130	130
B-10m-L	50	50	70	70	90	150	150	150	130		

Figure 10. Optimal operation conditions

5. CONCLUSIONS

The following conclusions can be made according to the variations carried out for each parameter:

- Stagger: The linear stagger presents a lower wear than the sine, for all conditions of speed, static force, pantograph model or distance between supports.
- Distance between supports: From the point of view of current collecition the models with a distance between supports of 8 m are associated with a more stable dynamic behavior. Nevertheless, minor wear values are obtained for distance of 10 m.
- Speed: Higher values of speed produce a higher system instability and therefore a lower quality of current collection. Also, the increase in speed leads to an increased of pantograph wear.
- Static forcé: The static force, as well as the speed, both mainly determines the quality of current collection and the generated wear. It has been observed that depending on the speed there is a static force optimal from the point of view of current collection quality and pantograph wear.

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