

Rail Steel Composition and Fatigue Life

The controlling of the initiation of fatigue defects in rail is now an important factor in rail maintenance strategies. A way to restrict the development of such defects is by use of premium steels with their greater strength values. Rail profile grinding also helps toward this end.

Both the uses of premium rail and profile grinding have been discussed in earlier columns (see RT&S, February 1986 and December 1986). Greater attention, too, is being focused upon the use of 'clean' rail steel as a means of improving rail fatigue life—that is, using steel with improved metallurgical cleanliness.

During the last several years, existence of a relationship between fatigue defects, in particular shell/detail fractures and the presence of nonmetallic impurities or inclusions has been demonstrated by various researchers! In fact, nonmetallic inclusions appear to play a significant part in the initiation of shell defects that are located just below the work-hardened layer in the head of the rail. Since it is from these shell cracks that transverse defects can develop, the presence of nonmetallic inclusions can thus be associated with the transverse type of fatigue defect found in rail.

Inclusion area counts

The nonmetallic inclusions noted can be either oxide¹ or silicate types.² In either case, however, the size of these inclusions and their 'amount' (as defined by their relative area) or "area percent" appear to affect the fatigue strength of the rail steel.

In Figure 1, the sizes of the inclusions that can result in fatigue defects are related directly to axle load.² In an analysis described for a static 33-ton (30-Tonne) axle load, the maximum inclusion diameter was found to be 70 micrometers. For a

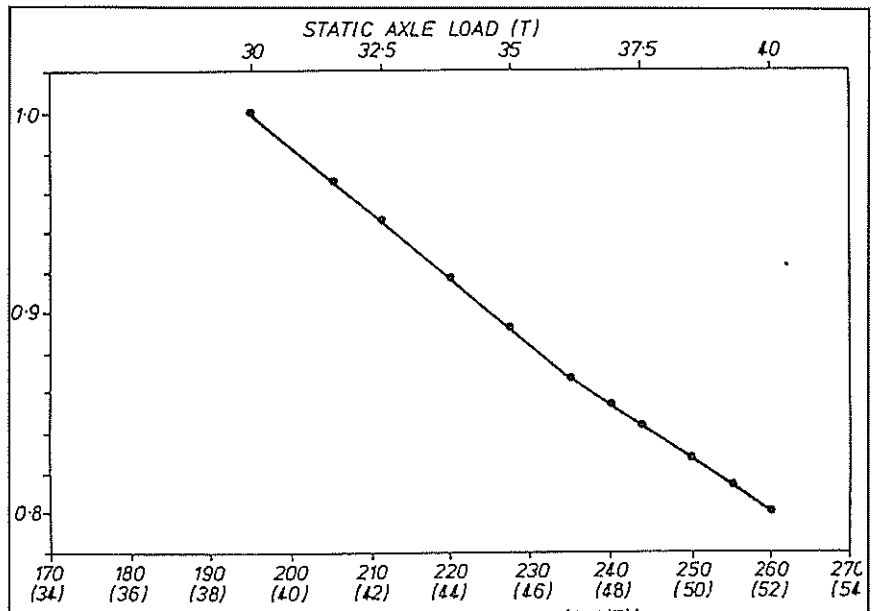


Figure 1 — Influence of load on relative threshold inclusion diameter.

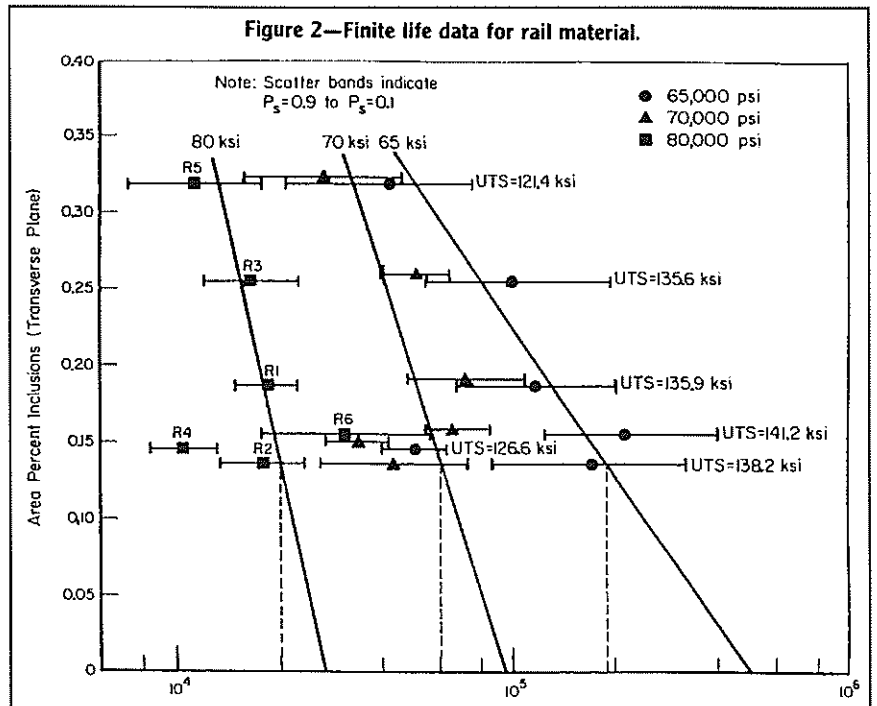


Figure 2 — Finite life data for rail material.

38.5-ton (35-Tonne) axle load, this maximum inclusion size dropped to 62 micrometers. Obviously then, the size of individual inclusions can be controlled to extend fatigue life.

Moreover, there also appears to be a relationship between fatigue life and the amount of inclusions within a given cross-sectional area in the rail. Figure 2 illustrates this.¹ It relates the percentage of inclusions within a transverse plane of the rail (area percent) and the life, in loading cycles, of the rail steel.

It can be seen in this figure that fatigue life increases as the area percent of inclusions decreases. Consequently, increased steel 'cleanliness' from a reduction in inclusions appears to result directly in increased fatigue life.

Greater cost for greater life

Extrapolation of certain limited test data indicates that reduction in inclusion content from a level of 0.14 area percent to zero can bring about an extension of rail fatigue life of between 50 and 200 percent.¹ In terms of cost, the achievement of 100 percent extension in rail fatigue life is found to be worth an additional investment of \$450 per ton for premium rail over the present cost of standard carbon rail. The economics here is based on net present value analysis.

As was noted at the beginning of this column, other methods exist for increasing rail fatigue life. Again, one is the use of premium rail steel as an economical alternative to obtaining metallurgically clean rail steel. Premium steels can be of an alloy type and/or heat-treated, thereby having increased hardness and strength. At a cost 25 to 50 percent above that for standard carbon steel, the pre-

mium steels may improve rail fatigue life by approximately 100 percent.

Another alternative in extending rail fatigue life is the use of improved maintenance techniques such as rail grinding, which can upgrade fatigue performance at a competitive cost.²

Finally, it must also be pointed out that similar to the area of inclusion vs. rail life relationship defined above, a connection has been found between rail fatigue life and ultimate tensile stress (UTS) of rail metal.¹ As a consequence, rail fatigue life increases with a rise in ultimate tensile strength of the rail.

However, since UTS is found to be related to the metallurgical cleanliness of rail, it is not clear at this time whether the consequent increase in rail fatigue life is due to improved cleanliness alone, or if the increase in the UTS inherently plays a part. If the latter applies, it might then be possible to achieve rail fatigue life benefits directly by increasing the strength of the steel.

Whatever the case, it does appear that there are gains to be made with the use of improved steels. As a consequence, the individual railroad must judge the economics of a given situation when deciding upon the most cost-effective approach to increasing the fatigue life of its rail.

References:

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