7. Design for Fatigue Resistance

7.1. General

Designing for adequate resistance to fatigue is the most important consideration in design of crane runways. Fatigue driven cracks in or around welded joints are known to occur in many Class S4 to S9 crane runway girders, at some time in service and before reaching their design life. Below Class S4 the number of load oscillations is too low for fatigue damage to start. Fatigue cracking has been widely reported (references 31, 40, 42, 50, 57, 59, 66, 74, 78). However not all problems are reported in the literature because the owners carry out repairs at shutdown times and make no reports.

Invariably, the causes of fatigue damage include the following:

- excessive stress range between the maximum and minimum stress
- underestimated number of load applications
- poor workmanship in carrying out the welding
- biaxial stresses (detail design)

Unlike in the design for strength, it is not possible to improve fatigue life by choosing a higher grade steel. The stress range concept is only concerned with stress concentrations and discontinuities associated with welding and notches. Because welding is used in the girder construction there is no point in using higher strength steel.

7.2. Stress analysis

The usual design practice is to first attend to the strength design and the check the design for fatigue. This is not the best order of events for more fatigue-prone structural Classes, S5 to S8 where it is best to start with fatigue assessment then choose the appropriate girder section and recheck fatigue. The strength verification of overload condition can then follow.

A separate elastic stress analysis must be carried out for fatigue verification. Plastic analysis is inappropriate for this purpose.

The possibility of fatigue damage occurring before the design life of the runway has been reached should be reduced to a minimum by carrying out a fatigue cognisant welded detail design and by carrying welding inspections for Detail Class SP. to ascertain that the girders are initially free of cracks. This should be followed up with periodical welding inspections.

The main attention should be given to structural and non-structural details and in particular to welded joints involved. The highest fatigue resistance is obtained where no welding and notches are present. Welded joints in general contain numerous imperfections that originate from stress concentrations such as undercut, over reinforcement, porosity, slag inclusions, lack of fusion, to mention just the more common ones. These imperfections may not be large enough to result in fracture under predominantly static loads. Quality assurance must effectively eliminate any imperfections larger than the limit given in the welding code. The designer's task is to avoid as far as possible the welded details that reduce the fatigue resistance such as, for example, welding across tensile flanges.

7.3. Number of stress cycles

The load combinations for which the fatigue resistance must be verified are those involving frequently applied loads, given in AS 4118, Table 5 as load combinations LC1 to LC3. Since the fatigue resistance depends on the stress range and detail category, the upper and the lower limits of cyclic loads should be carefully examined.

Crane runways in steel mills, alumina smelters, warehouses and many other applications are subject to millions of stress fluctuations in their service life while workshop cranes may not reach 100,000. The stress fluctuations vary in intensity and frequency. The purpose of the Structural Classification in AS 1418.1 is to arrive at the number of 'normative' stress cycles of uniform amplitude rather than using variable amplitudes as in real life. Then again local areas may be subject to higher class, as for example, in the top flange region where two or more wheels in the end carriage produce several stress cycles each time the crane passes.

In practice cranes may be subject to a heavier duty than that obtained by application of the code rules, as has been repeatedly found in investigations of fatigue cracking. To ascertain, in more important installations the most reliable estimate of fatigue parameters it is necessary to carry out time-and-motion analysis such that the upper limit of stress cycles can be established.

The number of cycles for fatigue verification of the runway structures depends on the 'structural class' as can be seen from Table 3.

Table 3. Number of normative stress cycles for fatigue design

Crane structure Class	No. of cycles for design
S1 to S3	0
S4 and S5	100 000
S6 and S7	500 000
S8	2 000 000
S9	5 000 000

The number of load cycles relevant for fatigue assessment is given in AS 1418 Part 1 and in Table 2 herein. It should be noted that fatigue assessment is concerned with stress ranges, not maximum stresses. The loads not included in the stress range calculation are the dead loads of the runway, rails, power conductors, the crane itself and all those loads that occur less than 20000 times over the service life. AS 4100 specifies that all loads are to be applied at their serviceability level, that is with load factor ϕ=1.0 but the dynamic factor has to be included. Only the load combinations 1, 2 and 3 need normally be considered except in high-risk applications (Heavy Duty) where load combinations 1 to 6 may need to be included.

Crane Runway Girders

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