Fatigue estimation for beam structures using BS5400

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ABSTRACT

In the vehicle industries the life estimation is getting more and more important. The old way was the stress comparing with a limit value. The result was a safety factor.
A damage calculation method will be presented in this paper which can be based on dynamic simulations and BS5400 standard [1.] and the all of the processes are integrated under the ANSYS FE system. We would like to show the validation on a test bench and an example of a global bus structure.

Keywords: Fatigue estimation, BS5400, FE, ANSYS, steel

1. INTRODUCTION

The North American Bus Industries is a well-known company in the American Market. It manufactures over 700 bus per year. This number consists of at least 4 different types. There is no big difference between two types, but we need to check the differences as fast as possible, therefore we use shell-beam mix model. The beam elements have a big advantage: very fast generation and calculation time. The other side, the disadvantage is the lower accuracy. We will get the nominal results for the structure and we can not see the local effects.

The necessary inputs for BS5400 are the nominal stress and the one-dimensional load structure. That is the reason why this standard is so good for life estimation of beam structures.

2. THEORETICAL BACKGROUND OF BS5400

The BS5400 standard is a standard for Steel, concrete and composite bridges, but some part is also correct for other field of design and research. The inputs are the following: detail class, range, cycles and probability of failure.

In the standard there are 9 different classes: W, G, F2, F, E, D, C, B, S. The worst class is the W and the best is the B. (The S is a special class for shear connectors.) Some class definition can be seen on Fig.1.

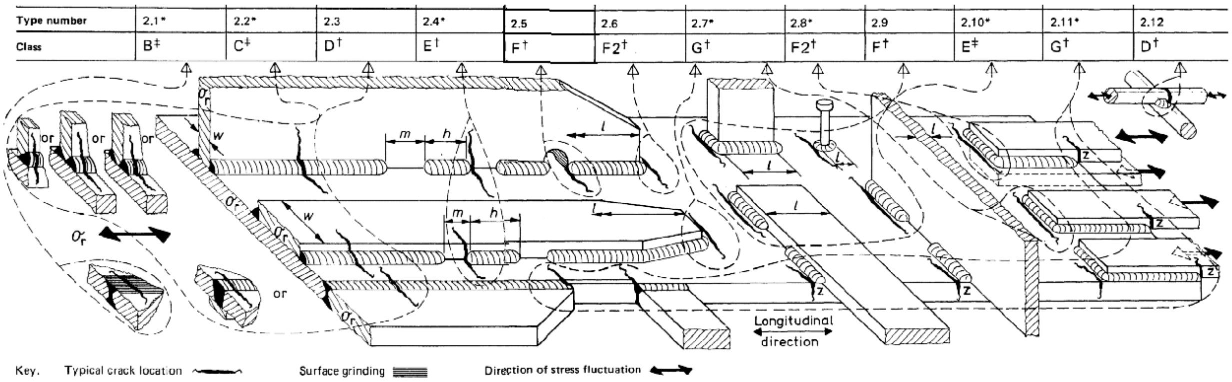


Fig.1. One of the tables for the class definition

The range (σ_r)-cycles(N) relationships have been established from statistical analyses of available experimental data (using linear regression analysis of log σ_r and log N)with minor empirical adjustments to ensure compatibility of the results between the various classes.

The equation may be written in basic (Wöhler curve) form as:

$$N \cdot \sigma_r^m = K_0 \cdot \Delta^d$$

where

N is the predicted number of cycles to failure of stress range σ_r
K_0 is the constant term relating to mean-line of the statistical analysis results
m is the inverse slope of the mean-line logσ_r – log N curve
Δ is the reciprocal of the anti-log of the standard deviation of log N
d is the number of standard deviation below the mean line.

For example the values for W detail class are shown in table 1.

K_0	Δ	m	d (probability of failure = 16%)
$0.37 \cdot 10^{12}$	0.654	3	1

Table 1.

The stress range-cycles diagram for D to G classes can be seen on Fig. 2.

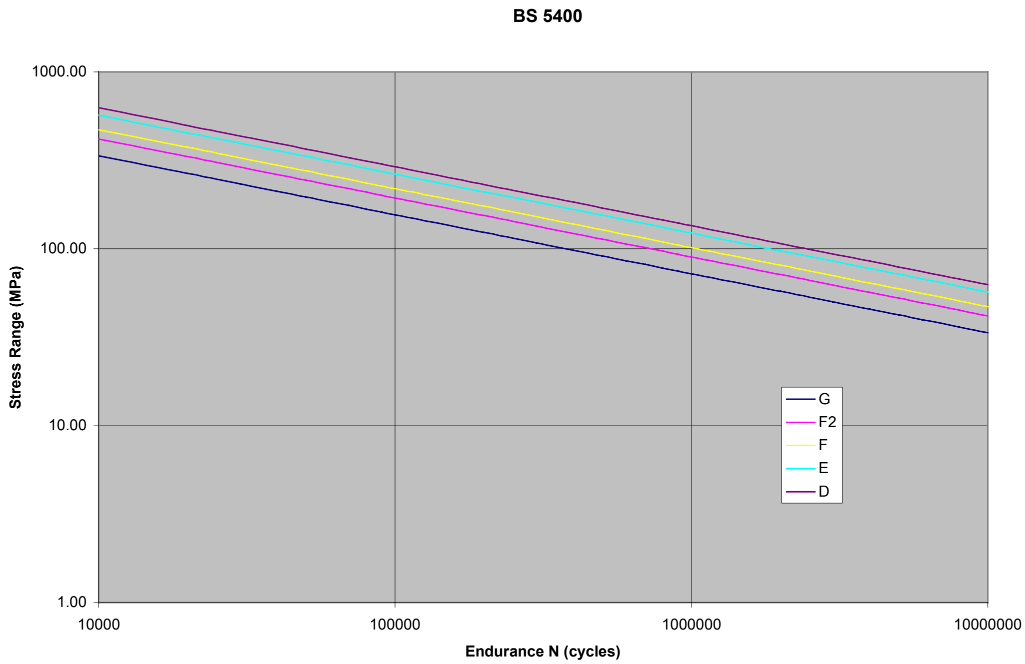


Fig. 2. σ_r – N curves applied by BS 5400

3. CHECKING OF BS5400 STANDARD

The first step was checking the standard with our test results. The test specimen was a T joint from St37 material. (Fig. 3.) The test series were made in AUTOKUT [2.]

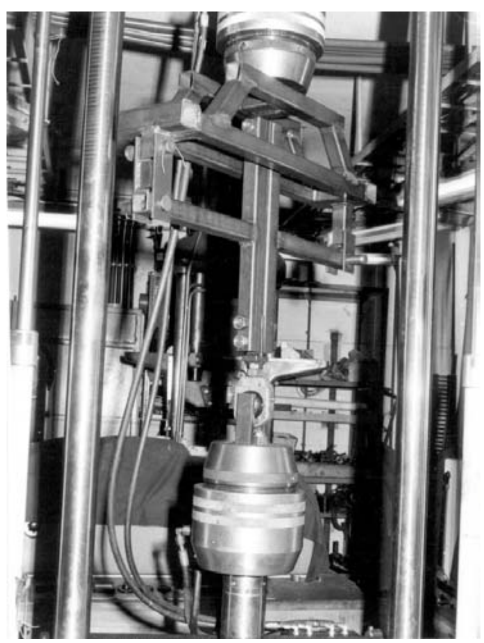


Fig. 3. Test Bench

The differences can be seen on Fig. 4-6. All cases we used F categorie ($K_0 = 1.73 \cdot 10^{12}$, $\Delta = 0.605$, m = 3, Probability of failure is 50 %, d = 0). The Fig. 4 shows the measured data with r = - 1 and r = -0.5 assimetric ratio. The Amplitude stresses were 147 and 150 MPa. The calculated value was printed with cross sign.

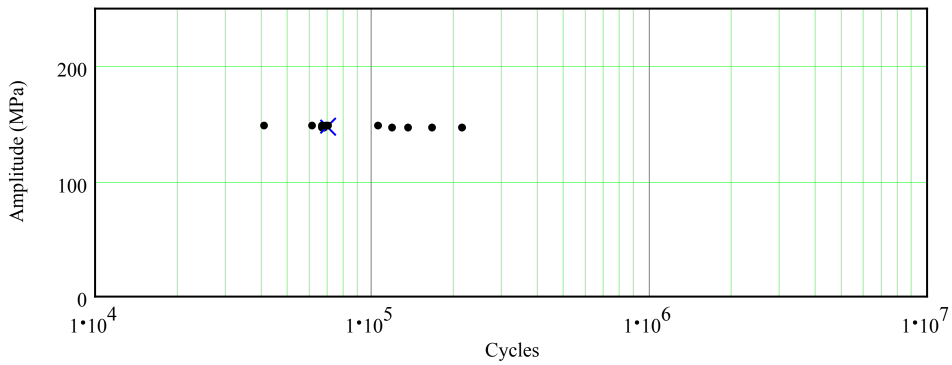


Fig. 4. r = -1, -0.5 , σ_a = 150 MPa

The Fig. 5. shows measured data with r = -0.5 and r = 0.05 assimetric ratio with 106 MPa amplitude stress. The data on Fig. 6 were measured with 88 MPa amplitude and the assimetric ratio was the same as on Fig. 5.

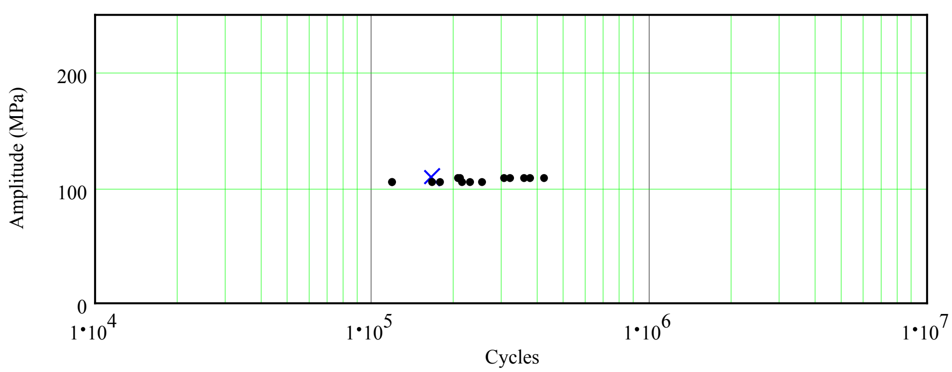


Fig. 5. r = -0.5 , 0.05 , σ_a = 106 MPa

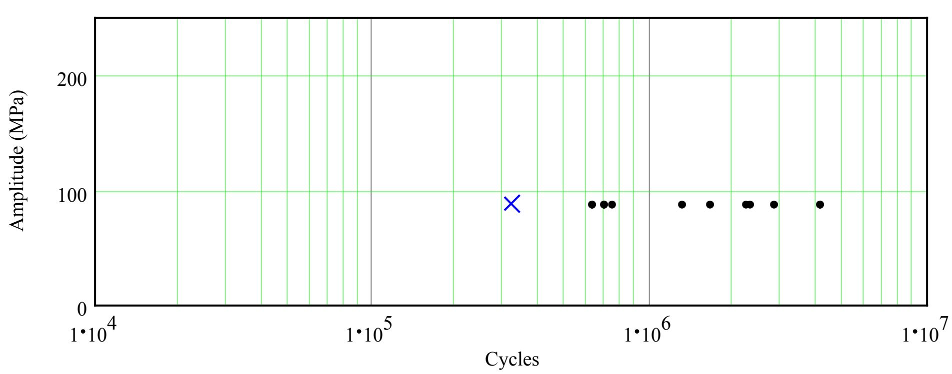


Fig. 6. r = -0.5 , 0.05 , σ_a = 88 MPa

The calculated N cycle is always on the safety side. Some cases we got much lower fatigue limit then the test, but it comes from the inclination of the S/N curve (Fig. 7.). In the BS5400 standard the inclination is always 3 except the last 3 detail classes. Another reason is the lack of the mean stress effect. We use the same S/N curve for all mean stress value therefore the deviation is higher.

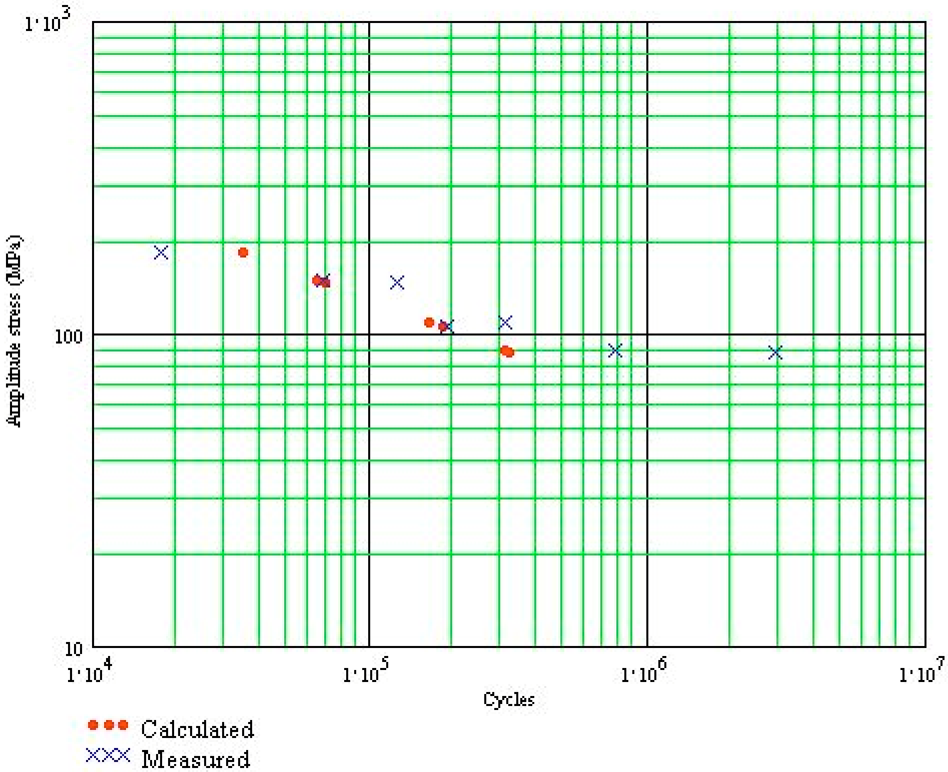
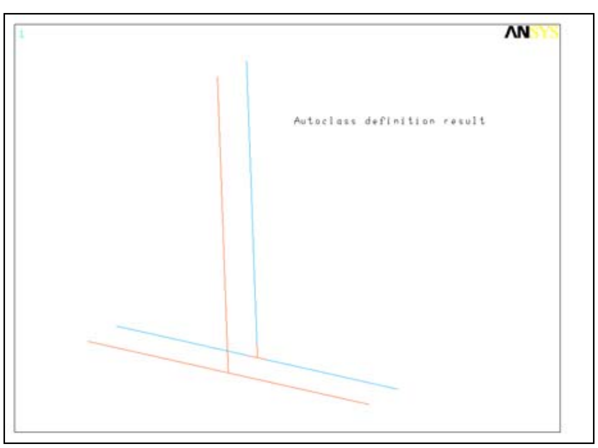
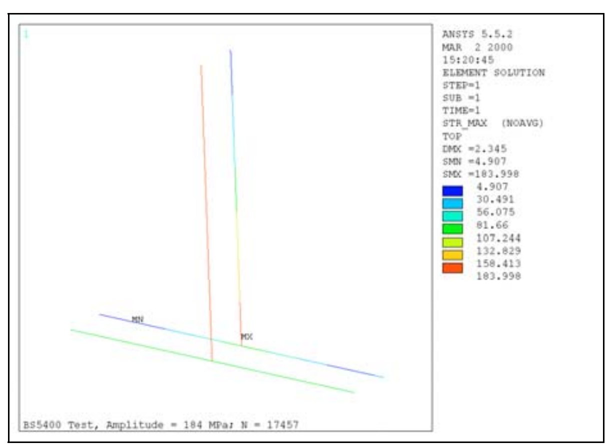


Fig. 7. S – N curves

3. USING BS5400 STANDARD ON A SIMPLE T-JOINT





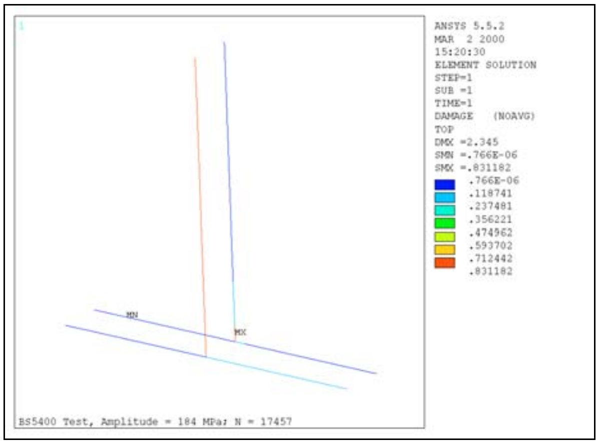


Fig. 8. a: model, b: stress ranges, c: damages

The application can be seen on the Fig. 8. The first figure contains the finite element beam models with BS5400 class definition. One of them is from 3 elements the other one is from 30 elements. The second picture presents the stress ranges. The third one shows the calculated damages. A very important conclusion can be drawn from this picture. There is no significant difference between the two models independently of the number of elements.

5. SIMPLIFIED SIMULATION OF A BUS STRUCTURE

The tubes in the model are from beam elements, paneling is from shell elements, masses are from solid elements and mass points. In general a beam model approximately contains ~8000 elements and ~6000 nodes. The presented model has the front low floor part from shell elements that are evaluated by DIN Standard. The number of elements is ~20000 and number of nodes is ~15000.

The bus analysis consists of some different load cases. These are the followings:

- gravity
- acceleration
- braking
- turning
- lifting

The final process is the summation of all damages. The damage limit is 1.

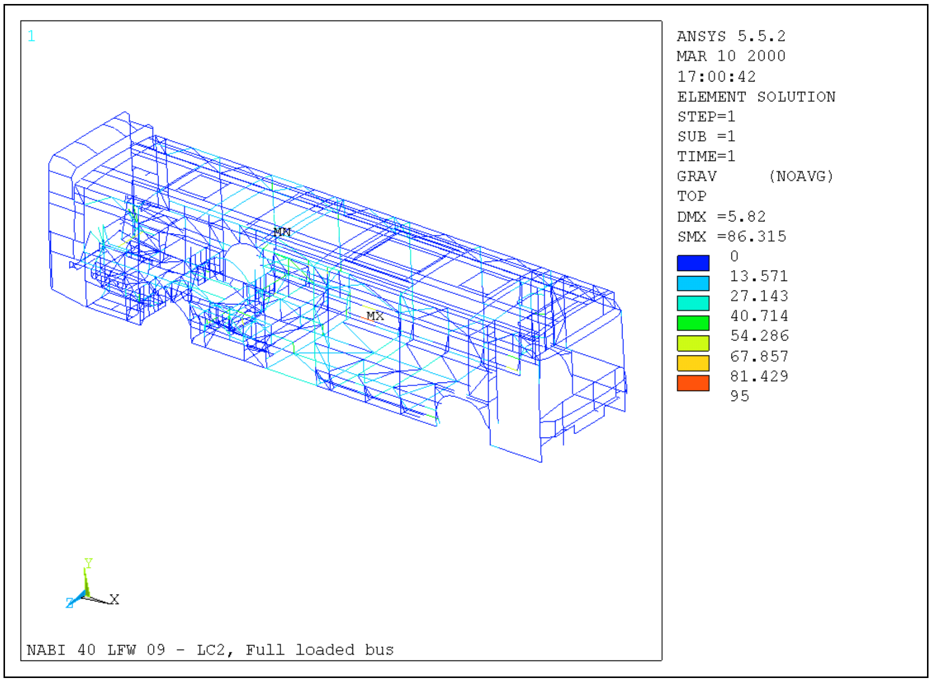


Fig. 8. Stress state (range) from gravity

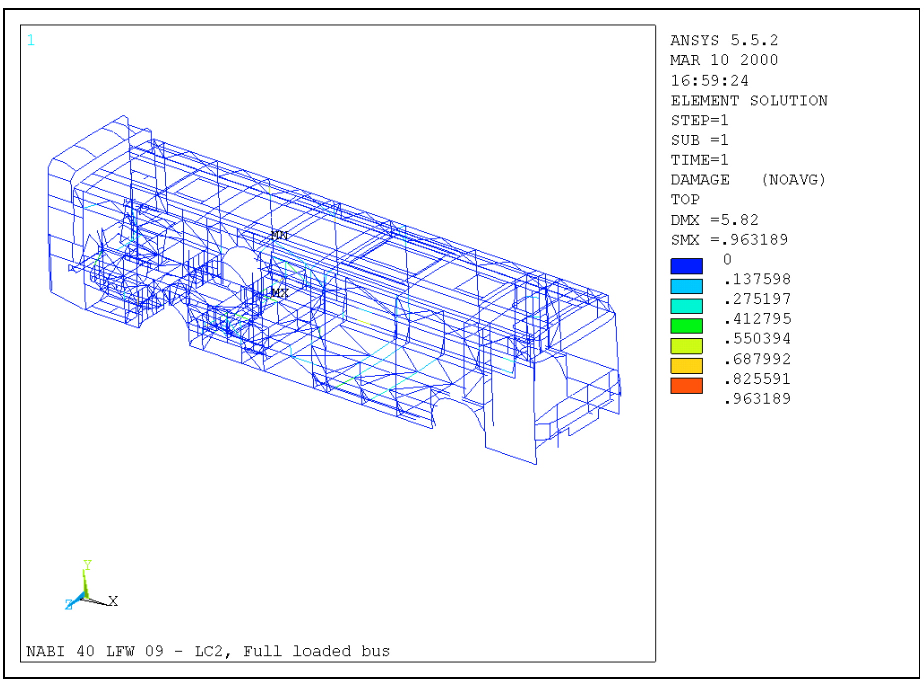


Fig. 9. Calculated damage values, $N = 2*10^6$

In case of dynamic simulation and rainflow counting this procedure can be used as well.

6. Conclusion

The presented method can be suitable for fast (life estimation) analysis of large structures. The damage does not depend on the element size in case of classical beam elements.

The results are to be handled carefully due to the lack of the mean stress effect and any material specification as well as inaccurate S-N curves.

Because of the above mentioned characteristics this Standard is appropriate for measurements on whole buses where the mean stress coming from gravity cannot be taken account on a simple way.

Additional advantage is the very simple programming so it is easy to apply for calculations.

References

[1]. BS5400:Part 10 : 1980 – Steel, concrete and composite bridges

[2]. Vizsgálati értesítő: Zártszelvényű csövekből készített merőleges kivitelű hegesztett próbatestek fárasztóvizsgálata a bekötötő csővel párhuzamos irányú terheléssel. Budapest 1989.

[3]. E. Kerekes, J. Petrovics: New Features in ANSYS developed by NABI FE Group, 18th CAD-FEM Users' Meeting 2000 International Congress On Fem Technology, September 20 – 22, 2000, Friedrichshafen