

Failure safety check of the folding staircase

(Doc. Ing. Milan Růžička, CSc., Czech Technical University in Prague, Technická 4, 166 07 Praha 6, Czech Republic, ruzicka@fsid.cvut.cz)

Assignment:

Determine the safety in face of static and dynamic loading of the two variant of the folding stairs. Discussion about probabilistic of fracture and reliability aspect of the both variants staircase arm design.

Comments to the process of the analysis:

Occurrence of the operational static failures on the arm of the folding stairs (see Fig. 1) forced the producer to make arrangements to raise its safety At first the analytical static loading analysis was made.

The computational analysis of the internal loading forces on the folding staircase arm was made. These loadings parameters were for the finite elements stress analysis (FEA) used. FEA on the three different models and shape of the arm cross-section (see Fig. 2) of purpose to optimise stress concentration was performed. These results were verified using static and dynamic experimental strain-gauge measurement (see Fig. 3). These results showed the variety of the loading conditions which were taken into account in SBRA method. The Monte Carlo probabilistic simulation of the loading cases and material parameters for different design variants of the arm was then applied to predict failure safety of this product.



Fig.1 The folding stairs

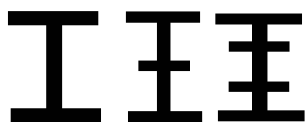


Fig.2 The different cross-section of the staircase arm

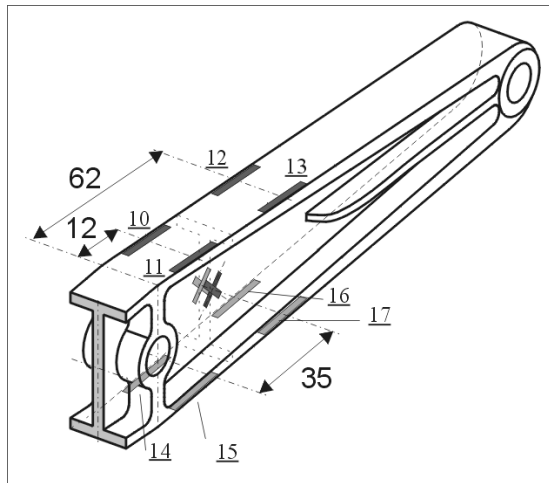


Fig.3 Positions of the strain gauges for the experimental stress analysis

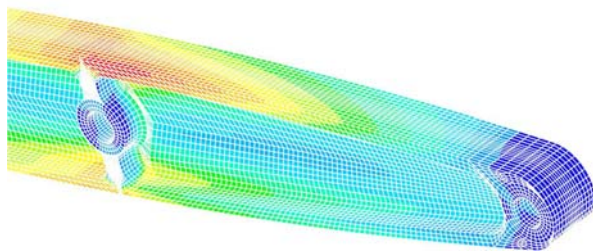


Fig.4 FEA results of the first loading case on the primary shape of the arm

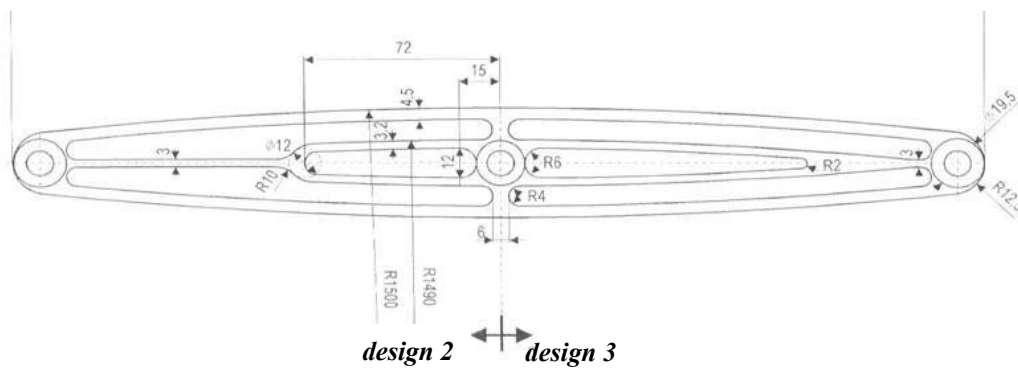


Fig.4 The two new designs of the arm shape

Input:

As the input parameters were generated:

- mass of the body m with the normal distribution (mean value=80 kg, st. deviation 26.4 kg, min. value 50, max. value 130 kg)
- dynamic coefficient k_{dyn} with the exponential distribution (mean value=1.3, st. deviation 0.3 kg, min. value 0, max. value 5).
- strength of material for two types of Al-alloys with normal distribution
 - R_{m1} : mean value=275 MPa, st. deviation 19 MPa, min. value 210, max. value 335 MPa
 - R_{m2} : mean value=290 MPa, st. deviation 12 MPa, min. value 220, max. value 355 MPa
- stress in the critical point of the arm for old and new design of the arm with the normal distribution according FEA analysis for the body mass $m=100$ kg.
 - $s1$: mean value=68.6 MPa, st. deviation 24.6 MPa, min. value 40, max. value 160 MPa
 - $s2$: mean value=45.5 MPa, st. deviation 17.5 MPa, min. value 30, max. value 120 MPa

Results:

At first the operate stresses calculated by FEA for $m=100$ kg were on the generated mean body mass $m=80$ kg recalculated. Subsequent the safe factors for both old one and new design of the staircase arm were determined:

$$k1=R_{m1}/sig1$$

$$k2=R_{m2}/sig2$$

$$sig1=s1*80/100*(m/80*(1+k_{dyn}))$$

$$sig2=s2*80/100*(m/80*(1+k_{dyn}))$$

Comparison of Results and Conclusions:

As show the tables and histograms on the Fig. 6 and Fig. 7, in the both cases the static safety of the staircases is higher as 2.18 and 3.33 (probability 50%). But while for the safety factor $k=1$ the risk of failure is 3.4% by the original old design of the staircase arm, is the same probability only 0.075% for the new design of the staircase arm. Fig. 8 and Fig. 9 shows result by the AntHill output programme for the above described failure probability.

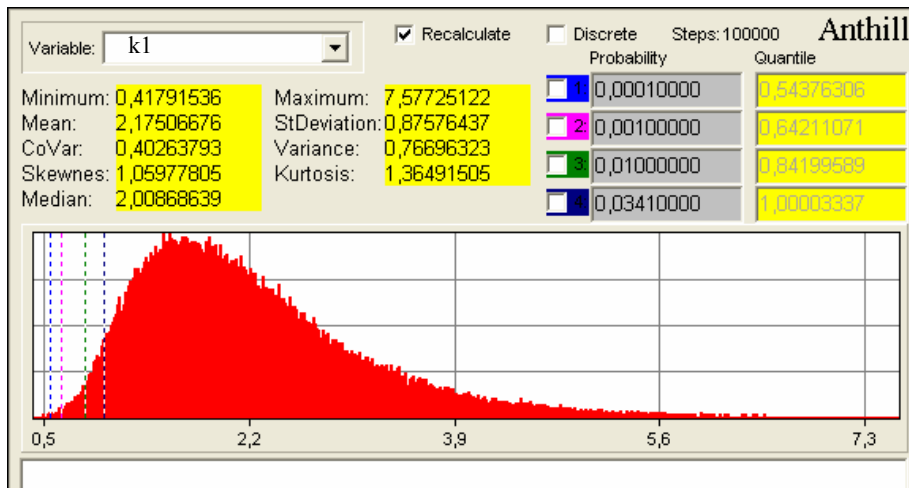


Fig.6 Histogram of the safe factor for the original old design of the staircase arm

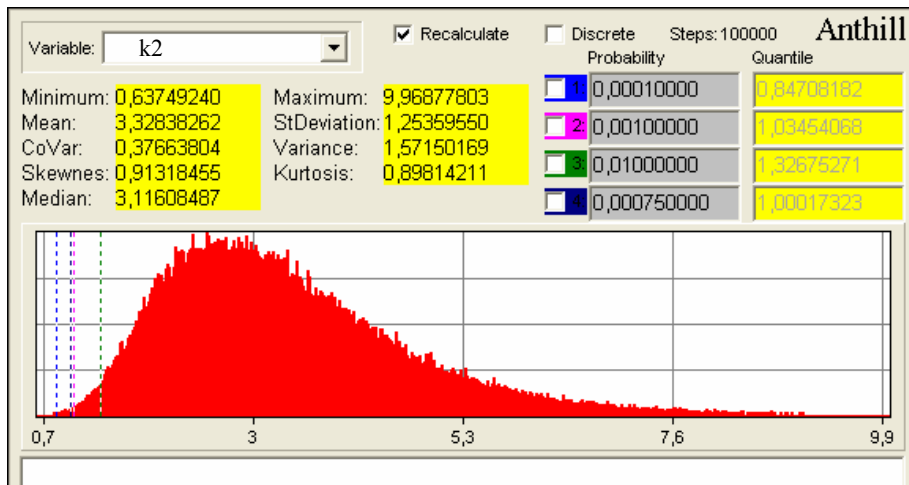


Fig.7 Histogram of the safe factor for the new design of the staircase arm

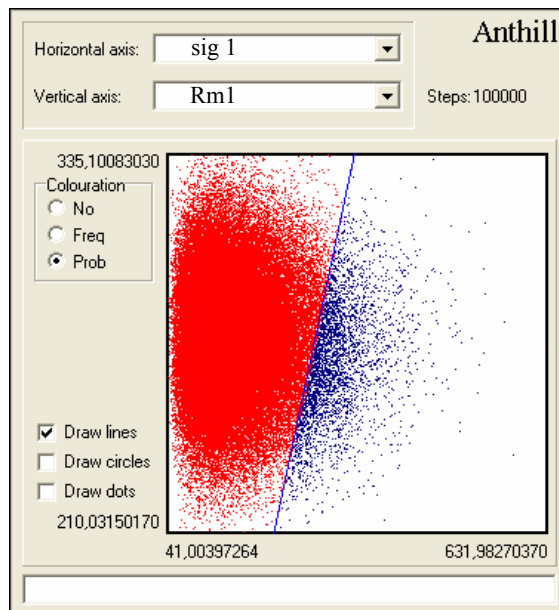


Fig.8 The Ant-Hill failure probability simulation the original old design of the staircase arm

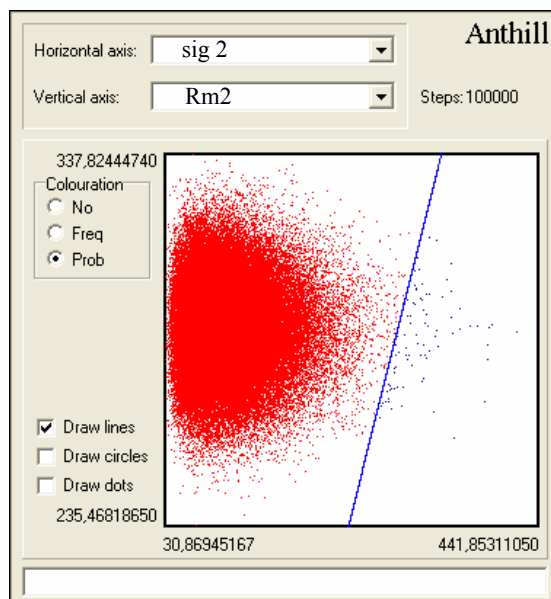


Fig.9 The Ant-Hill failure probability simulation for the new design of the staircase arm

References

1. Milan Růžička: Failure safety check of the folding staircase. In: Spolehlivost konstrukcí 2003, Ostrava. April, 23-24, 2003 .
2. Pavel Marek, Jacques Brozzetti, Milan Gustar (editors): Probabilistic Assessment of Structures using Monte Carlo Simulation, ITAM CAS CZ, Praha, 2001.
3. Milan Gustar, Pavel Marek: *Text formatting*. TeReCo - 2nd edition.