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Design and analysis of shaft and bonded joints for electric car gearbox

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Main goal of this work is to analyze loading of current steel input shaft of electric car gearbox and then design lightweight alternative version. Designed shaft will have hybrid construction from composite and steel parts. Gears will be bonded to the shaft, so it is necessary to do several shear experiments for choosing suitable adhesive.

At first the original steel shaft was analysed with unit force (1 000 *N*) and torque (10 000 *N·mm*) load to obtain deflection and rotation of the shaft. FE software Abaqus was used for this analysis. Then designed hybrid shaft was loaded in similar way for stiffness comparison. Several designed ideas of hybrid shafts were analysed with the – shaft with steel mandrel, shaft without steel mandrel (both versions have same lay-up), and shaft with steel mandrel with optimized lay-up. Comparison of deflection/rotation of designed version can be seen in Table 1.

Table 1. Comparison of deflection/rotation for designed versions

Version	Deflection [*mm*]	Rotation [*rad*]
Original steel shaft	-3.411e-04	-1.182 e-04
Designed hybrid shaft	-9.738 e-04	3.289 e-04
Optimized lay-up	-8.197 e-04	6.607 e-04
Hybrid shaft without mandrel	-9.863 e-04	3.327 e-04

Designed shaft will be tested on CTU´s experimental stand with maximal torque equal to 300 *N·m*. This torque was distributed to the shaft though the helical gears, so we have to compute the real loading of our model – radial, axial and tangential forces in gears and corresponding force, torque and bending moments in shaft. Values of deflection/rotation for real load can be seen in Table 2. Deformed FE model (displacement) can be seen in Fig. 1. Designed shaft (without steel parts and gears) can be seen in Fig. 2.

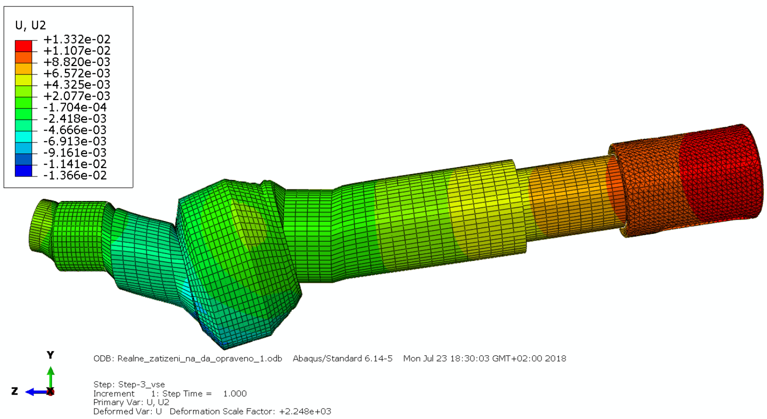

Fig. 1. Deflection of designed shaft

Table 2. Deflection/rotation for real load

Version	Deflection [*mm*]	Rotation [*rad*]
Designed hybrid shaft	-136.6 e-04	2.178 e-04

Fig. 2. Designed composite shaft

Real shaft will be manufactured by filament winding technology and gears will be bonded to the shaft. Several shar tests on flat specimens according to [1] were done to choose suitable adhesive. Six material combinations and eight adhesives were tested which means around about 225 specimens. Results of the experiments were average shear strengths for each type of adhesive/material combination – typical graph from shear experiment can be seen in Fig. 3. Experiments were also simulated in Abaqus with the use of cohesive elements and simulation results were compared with experiment. Based on the results from flat specimens, four adhesives were chosen for testing on tubular specimens steel/composite. Bonded joint was created with the use of injection technology.

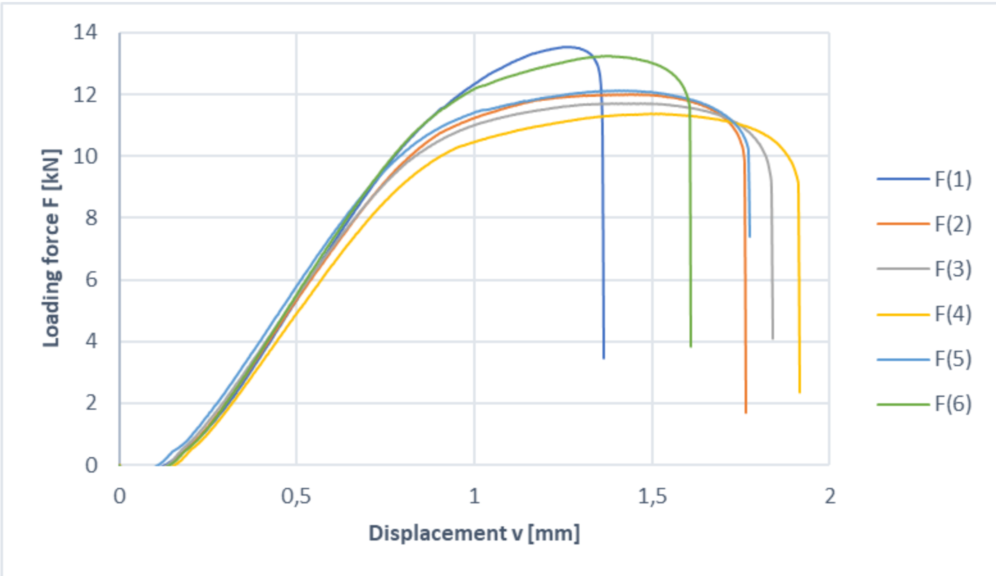

Fig. 3. Relationship between loading force and displacement for steel adherends and Acralock adhesive

Acknowledgements

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References

[1] ČSN EN 1465, Lepidla - stanovení pevnosti ve smyku při tahovém namáhání přeplátovaných lepených sestav, 2009.