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GEOMETRIC OPTIMIZATION OF SHAFT TRANSITION ZONE BASED ON STRESS-STRAIN ANALYSIS OF NATURE INSPIRED DESIGN

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The presented research primarily considers with the geometric solutions that Nature has optimized. In the study presented in this paper, the nature inspired transition shapes are used in the research of innovative design and geometric optimization of transition zones of the high-loaded shafts. The basic inspiration is found in the geometry solutions of the Nature in the case of trees [1, 2]. The transition zones that Nature chose and designed on trees in many cases survived for more than a hundred years, resisting on the various and variable external loads and other external conditions. Prof. Mattheck was one of the scientists who realized the potential of the research of the way on which trees grow for engineering purposes [1]. He found that the transition zone created by Nature can be explain as a series of isosceles triangles, in which each subsequent triangle has a leg equal to a half of the hypotenuse of the preceding one.

For the geometric optimization with transition zones inspired by Nature, a particular shaft with flange is chosen and presented in this paper, [3]. This shaft is a real horizontal hydro turbine shaft with significant radius change at transition zone from shaft to runner flange, which is out of standard engineering ratios and was the cause of failure [4]. The radius signed with (a) at Fig. 1 shows the traditional engineering design of the shaft to flange transition zone characterized with single radius arc of r=80mm. The Finite Element Analysis (FEA) is performed in previous phases of the research for all load variation during shaft operation, as well as arc radius variation [5]. The possible benefits based on the nature inspired design for increasing fatigue resistance of a high-loaded shaft transition zone are confirmed by correlation of FEA performed for traditional design and FEA performed for nature inspired design of a shaft transition zone, [3].

In order to perform a geometric optimization of the nature inspired design of a transition zone at a high-loaded turbine shaft, the optimization of the size of the triangles that simulate the trees' inspired transition design is performed. In the particular case study, three cases are modeled (marked as "case 1", "case 2" and "case 3"). For "case 2" the leg of the first triangle has a length for a quarter less than in the "case 1", while for "case 3" the leg of the first triangle has a length for a quarter more than in the "case 1". The simulations of these cases of the nature inspired design are shown in comparative drawn in Fig. 1(a). The obtained generatrices for all considered cases of the transition shaft to flange zone are shown on the common drawing in Fig. 1(b): (a) - for the traditional engineering design, (b) - for the nature inspired design "case 2", (c) - for the nature inspired design "case 1" and (d) - for the nature inspired design "case 3". The comparative stress-strain analysis is performed by FEA for all transition zone designs shown on Fig.1: the traditional engineering design and the three previously defined cases of the nature inspired design. The analysis is performed for the critical case of the external load, defined in accordance with the real operation conditions as the regime during starting [4, 5].

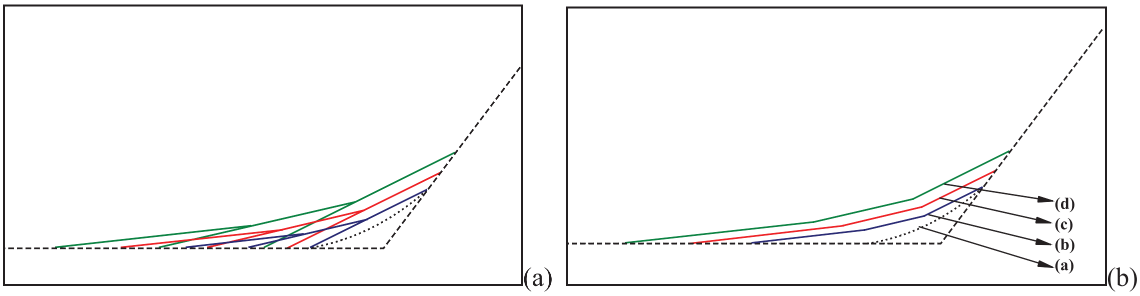

Fig. 1. Comparative drawn of traditional design and designs inspired by nature (a) and the obtained generatrices at a transition zone (b)

The obtained results for the maximal normal stresses, as well as for maximal equivalent Von Mises stresses are given in Tab. 1. The analysis of the obtained results shows that the stress distribution is changed with variation of the transition zone design, not only in the transition zone but through all volume of the studying shaft. It is undoubtedly that the new nature inspired design can gives improvements and increasing in load capacity. However, the obtained results lead to the conclusion that the geometric optimization of new proposed design is required in order to obtain expected improvement for a real mechanical element.

	σ_x [MPa]	**σ_x reduction**	**σ_{VM} [MPa]**
traditional design with *r*=80mm	119	/	127
new design - case 1	111	6.7%	128
new design - case 2	122	-2.52%	144
new design - case 3	106	10.93%	129

Table 1. Comparison of the obtained normal tensile stresses (σx) and equivalent VonMises stresses (σVM) for considered design cases

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