Monocolumns-to-portal transition reduces the crossing of oscillation between X and Y direction. It is important to secure the diametrical accuracy.

Coupling monocolumns into the portal is recommended to decrease machine tool vibrations if technological force frequencies are below 40 Hz. If cutting is more speedy, there is no need in additional reinforcement of monocolumn.

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FEA-AUDIT AND REDESIGN OF PRACTICE-PROVED CENTRIFUGE MACHINE

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Given work touches the compact, high-speed biological centrifugal machine, designed before FEA epoch, but permanently produced and exploited till now. So some kind of FEA-audit of old, intuitive design is provided here. Proportions of centrifuge load-bearing system (LBS) are optimized and proved by long-term practice. Collapses and partial cracking are not reported for all centrifuge examples.

The centrifuge works in the quasi-static mode with long time loading by constant centrifugal forces caused by stable rotation at the speed 4000 min^{-1}. Quantity of loading cycles (due to speeding up and running out) is not large for all service life. So static strength and, possibly, ratcheting (during low-cycle fatigue) are the main issues.

Some specific terms are proposed for explanations here below:

Critical point of surviving (CPS) – severe stress concentrator possesses next features simultaneously: a) almost inevitable in the design sense; b) haven't got a reservation if cracked; c) shortage of effective parameters to control the level of stress in it. It is obvious that CPS tied to different inner corners and fillets.

Fillet radius management (FRM) – need to vary fillet radius for CPS smoothing, causing no indirect damages and harmful consequences for nearby design.

Controllable contact spot control (CSC) – design approach aiming to reduce nominal contact interface to dimensions of expected virtual contact spot.

Fig. 1, a gives an outer view of the centrifuge's LBS. Fig.1, b depicts 1/6 portion of the full model. The section view on the rotating structural parts is given in fig.2. The set of parts consists of the aluminum rotor 1 (ø205 mm; six spokes 1S protruded radially from the hub 1H) and six aluminum cups 2 (height 162 mm), containing processed liquids in the flexible envelopes. Envelopes are replaced by weights 3. There is lug 1L at the end of each spoke. Lug holds steel pin 4.

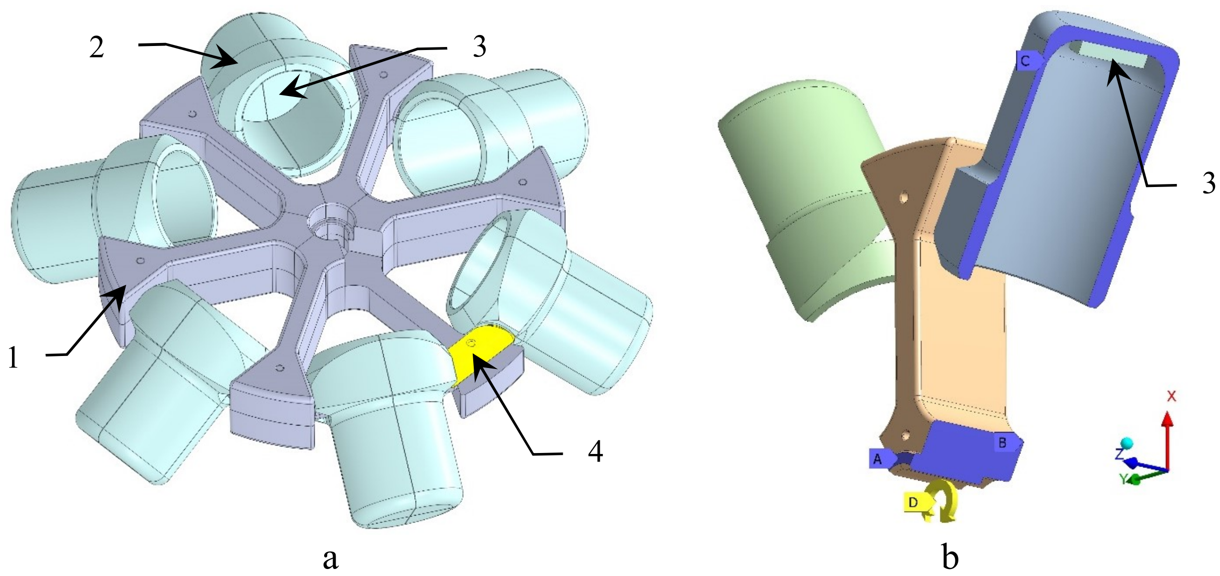


Figure 1 – Rotated load-bearing system (LBS) of the centrifuge (a) and symmetrical 1/6-part of the FEA-model (b): 1 – rotor; 2- cup; 3 – weight; 4 - pin

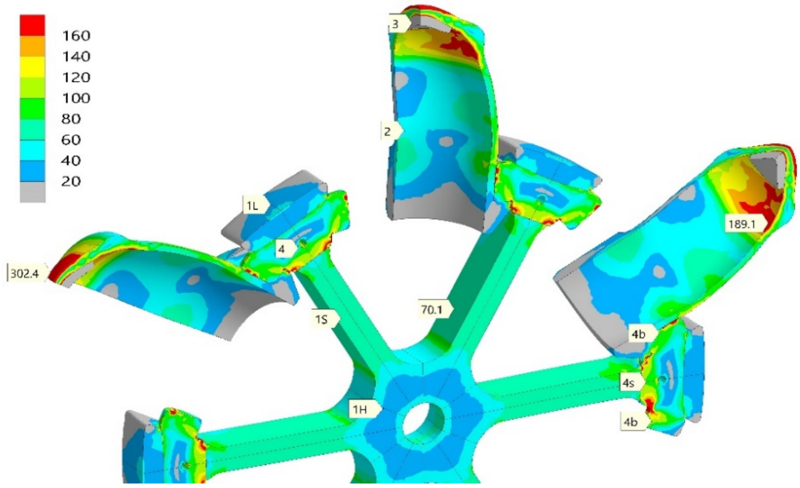
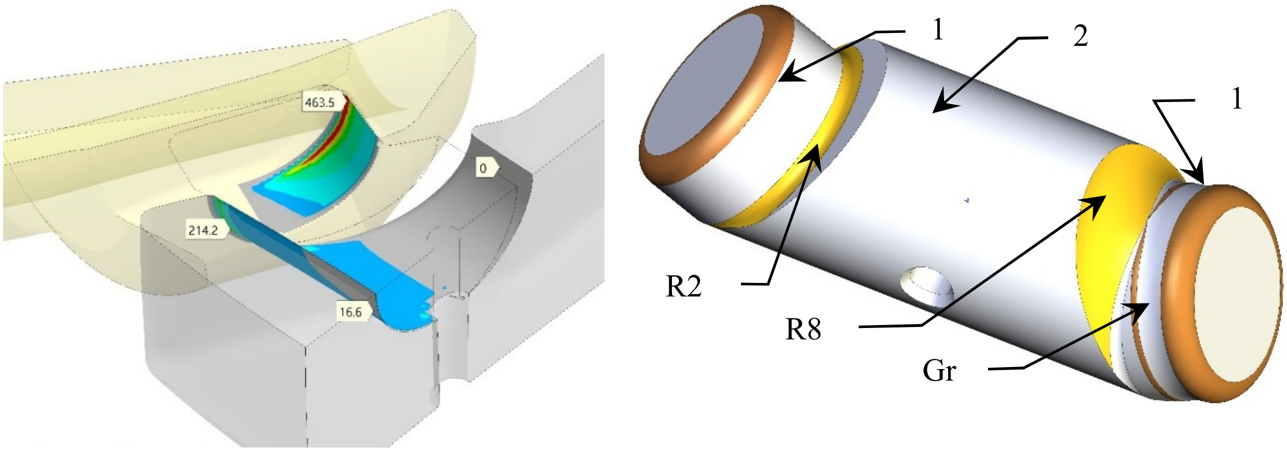


Figure 2 – Section view of the symmetrical ½ -part of the model with the distribution of the equivalent stresses σ_e (MPa); angular velocity $\omega = 420\,rad/s$. Marks 1L, 1S, 1H relate to the rotor 1; marks 4b, 4s – to the pin 4

Two neighboring pins 4 hold the cup 2 between spokes with the possibility of local rocking. Every pin possesses three cylindrical steps (fig.3). The central step of ø32 mm (2) is inserted into the spoke lug and fixed. End steps (bosses – 1; ø30 mm) stay in frictional contact with cups. Fillets with different radiuses (e.g. R2, R8) were investigated. The initial design states the radius of 1 mm (R1).

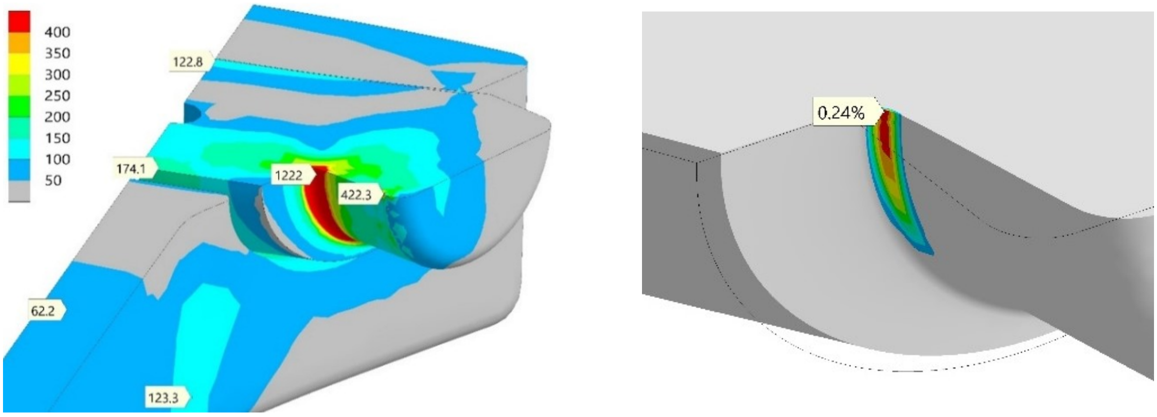
The strongest stress concentration is revealed on the pin fillet. Elastic solution EL for frictional contacts FC (fig. 4, a) shows equivalent stress (mark 1222) exceeding one and half times yield stress. Two-axial tension governs on the fillet surface ($\sigma_1 = 1351 MPa$, $\sigma_2 = 343 MPa$, $\sigma_3 = 0$). Elastic-plastic solution PL (fig.4, b) reveals significant plastic deformation on the fillet (mark 0.24%). It is an unsafe situation due to preliminary steel hardening. It may lead to the brittle fracture of the pin.



a b

Figure 3 – Compressing stresses (a; R1) in the contacts «pin (shown separately on b) – cup slot» (up to 463.5 MPa) and «pin stem – spoke lug» (up to 214.2 MPa)

The fillet should be taken as a specific object – critical points of surviving – CPS. One could see strong imminent stress concentration, on the one hand. On the other hand, the long service life of the centrifugal machine gives evidence of material surviving into the fillet region. It is possible, qualitative steel possesses durability resources even in the hardened state. The feasible issue may be an autofrettage effect. Anyway, stress relieving is desirable for pin fillet CPS.



a b

Figure 4 – Distribution of the equivalent stresses σ_e (MPa) in the pin (R1) and rotor lug (a – EL, FC) and plastic deformation focus on the pin fillet surface (b – PL, FC).

Pin fillet CSP attracts priority attention during centrifuge LBS optimization. That CSP needs to be smoothed out. Full CPS excluding is hardly possible. The evident measure is to fill in some way step between stem and boss for the pin.

Fillet radius management (FRM) is tied with the increasing of fillet radius. Initial radius value (R1) was changed to the 2, 4, 8 mm (design variants Des2, Des4, Des8 respectively). It is necessary to find the room for Des4, Des8 solution. Technics CSC could do it by contact interface decreasing (fig. 3, b – right end).

Double increasing of fillet radius preserves stress picture thought lowers peak tension stress. Stress σ_1 decreases from 1351 MPa (R1) to 883 MPa (R2). Only small plastic deformations are revealed on fillet in the last case.

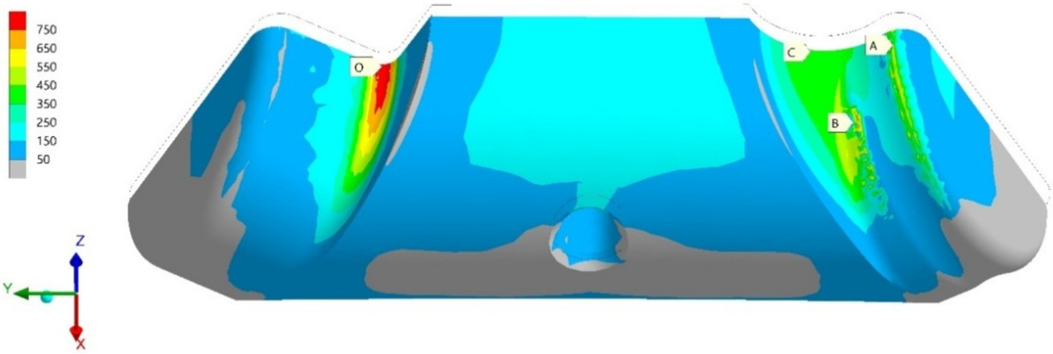


Figure 5 – Design variants R2 (left) and R8 (right) for the pin – picture of equivalent stress σ_e, MPa.

CSC technics proposes (fig. 5, right end) to increase fillet radius up to limit and exclude the pin step completely. The step would be overridden by complex surface C-A-B. Radius 8 mm is achieved in point C. Such overriding leads to the significant weakening of tension. Mark 470.99 points out moderate σ_1 stress. It is two times lower as for R2 (left pin end on fig. 5 – mark O). CSP is smoothed out.

Centrifuge simulations were provided for the range of pin fillet radiuses. The results are shown in fig. 6. Here designation SQE relates with fully elastic FEM-solution (EL). Designation S1E discloses peak value of maximal principal stress σ_1. Designation SQP refers to equivalent stress σ_e after the elastic-plastic (PL) solution. Stress σ_e is limited from above by yield stress of steel. Such limitation is accompanied by plastic deformation E5 (scaled in 10^5 times) accumulation on the fillet surfaces.

Designation Sh describes hydrostatic stress. Large Sh value points out volume tension state. It is dangerous for brittle fracture initiation. Structural stresses (by curves SQE, SQP, S1E, Sh on fig. 6) relatively rapidly go down as fillet radius increases from 0.5 to 4 mm. Stress decreasing decelerates after level R2 passes by. Plastic deformations (E5) are revealed at the fillet only for R2 and lower.

Contact pressure (Pres) begins to increase for R4 and higher. Implementation of the R8 variant needs to improve cup slot durability due to high contact stresses. Laser treatment may be fulfilled.

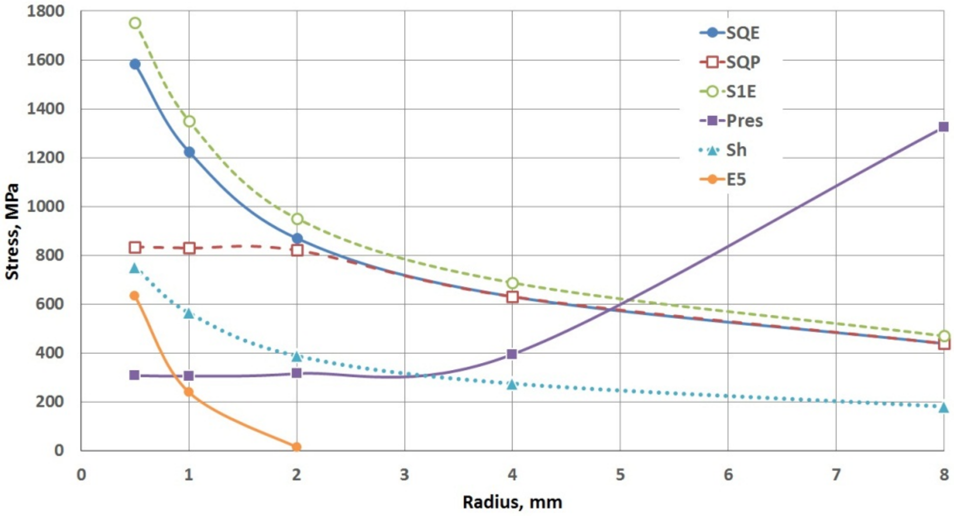


Figure 6 – Stress parameters and accumulated plastic deformation E5 on the pin fillet depending on the radius

Conclusions:

1. The set of critical surviving points (CSP) is revealed in the centrifuge load-bearing system (LBS). They are placed at the pin fillets.
2. Hardened steel undergoes localized plastic deformation in the CSP on the pin fillets. However, pins preserve strength as long-year exploit practice proves. Such kind of surviving needs special investigation. It may be due to the autofrettage effect.
3. It is proposed to smooth out pin CSP by fillet radius increasing. Stress concentrator smoothing is possible. Hence, in the limited design room, it brings the contact pressure growing caused by contact spot shrinkage.
4. Pin fillet radius 4 mm is the optimal one. Equivalent stress is lowered in 1.94 times in comparison with 1 mm with no significant contact pressure increasing (29% only). Simultaneously, hydrostatic pressure is declined in 2.05 times. It improves pin fillet protection from the brittle fracture.

УДК 621.793: 620.1

СНИЖЕНИЕ ШУМА ЗУБЧАТЫХ ПЕРЕДАЧ ПЛАКИРОВАНИЕМ РАБОЧЕГО ПРОФИЛЯ ЗУБЬЕВ

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Введение. Одним из путей решения задачи снижения шума зубчатых передач является обеспечение рациональной топографии рабочих поверхностей зубьев, которая может формироваться различными методами, в том числе и методом деформационного плакирования гибким инструментом (ДПГИ) [1, 2]. При реализации метода ДПГИ в качестве гибкого инструмента используется вращающаяся металлическая щетка с проволочным ворсом, а слой покрытия на