30th International Conference
ENGINEERING MECHANICS 2024
Milovy, Czech Republic, May 14 – 16, 2024

RECONSTRUCTION OF DUO ROLLING MILL

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Abstract: *Shown are design concepts for the reconstruction of an adjustable UD rolling mill (from the 90s) for a section mill train at domestic customer´s place. A finite element method was used to discretize the models in the elastic field using spatial elements. The strength evaluation consists in the assessment of assumed critical cross-sections and points from the point of view of a possibility of emergence of ductile, fatigue and sudden fractures, including the propagation of cracks. The SKALA program fully utilizes the results of the elasticity solution by the MARC system in the linear field, and the generalized Neuber principle is applied to a wide extent to determine the plastic deformations necessary for the assessment of service life (Pospíšil, 1976).*

Keywords: Design concept, DUO rolling mill, reconstruction, FEM, elasticity and strength evaluation.

1. Introduction - Device Description

In this paper is described a structural revision during the reconstruction of the DUO (two horizontal working rolls) rolling mill (Fig. 1). The rolling mill is used to shaping hot steel bars. In the DUO rolling mill, holes for anchors got worn (ovality, plastic deformations) in the lower frame (frame material 42 2712.5, R_m = 500 MPa, R_e = 280 MPa), where it was necessary to press on the bushings (to be lined - bushings made of material 42 CrMo 4 + QT , R_m = 700 MPa, R_e = 500 MPa) so that all the original linked-up components can be kept and thereby the costs saved. In the vicinity of the opening of the lower frame, there are potential critical points such as threads (M24) for shims and an inlet for cooling (Fig. 2). The design modification consists in enlarging the opening, pressing-on the bush and working it to the original internal dimension (Fig. 3).

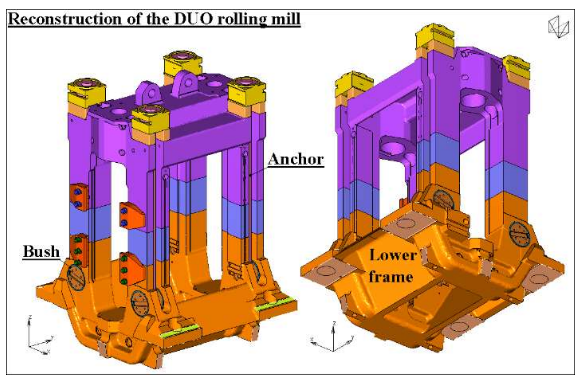

Fig. 1: The DUO rolling mill.

2. Boundary Conditions

The boundary conditions of the UD rolling mill are as follows (Fig. 4). Three different loading modes after pressing-on the bushings were calculated:

- The first loading was considered with self-weight and pre-loaded anchors, bolts, as the var. UDS15R, lower condition.
- The second loading was considered centric with self-weight and pre-loaded anchors, bolts, as var. UDS16R, upper condition.
- The third loading was considered eccentric with self-weight and pre-loaded anchors, bolts, as var. UDS17R upper condition.

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doi: 10.21495/em2024-206

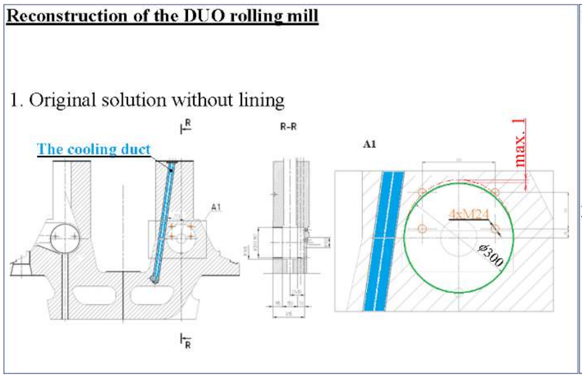


Fig. 2: Initial shape of the opening of the lower frame.

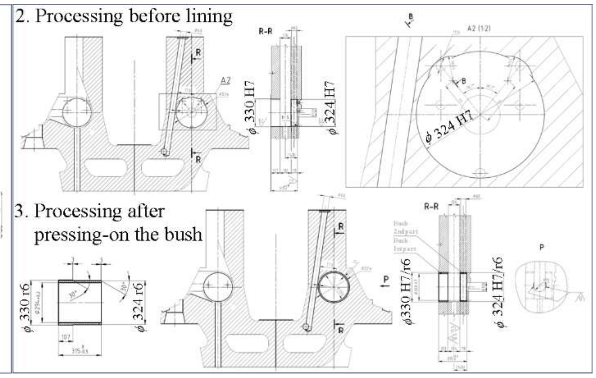
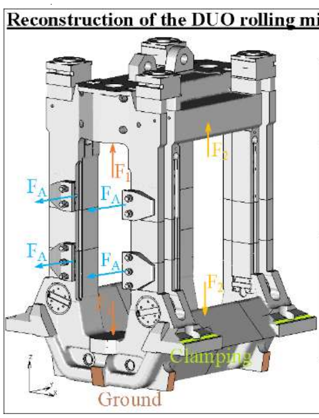


Fig. 3: Working before and after pressing the bushing into the lower frame.



	Variants	UDS15R	UDS16R	UDS17R
Loads	F_1 [MN]	-	1.5	2.0
	F_2 [MN]	-	1.5	1.0
	F_A [kN]	-	150.0	150.0
Preloading	Anchor [MN]	1.97	1.97	1.97
	Screw M48x3[MN]	0.40	0.40	0.40
	Screw M45x3 [MN]	0.39	0.39	0.39

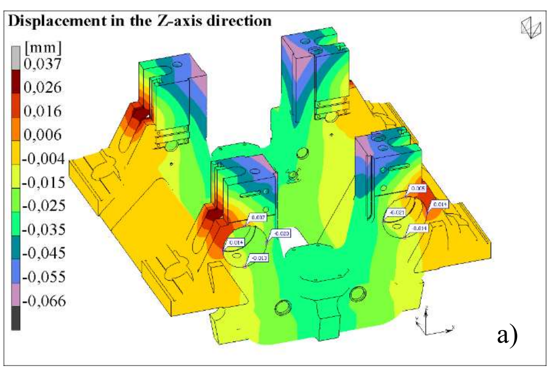
Fig. 4: Boundary conditions of the DUO rolling mill.

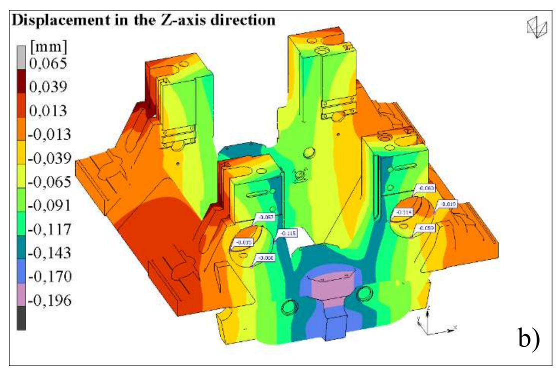
3. Results of elasticity calculation

Displacement in the Z-axis direction are in the Fig. 5. The figures show differences between individual variants. Hole deformations:

- var. UDS15R range from -0.021 to 0.014 mm.
- var. UDS16R range from -0.060 to -0.015 mm.
- var. UDS17R range from -0.127 to -0.017 mm.

The values correspond to the predicted results.





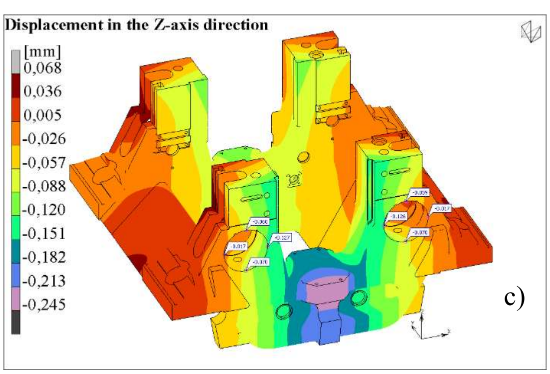


Fig. 5: Displacement in the Z of the lower frame for the loading variant a) UDS15R, b) UDS16R and c) UDS17R.

The first principal stress, design (reduced) stress SV (according to HMH) are shown in Figs. 6–9. On the basis of the first principal stress and design (reduced) stress (according to HMH), the places for strength assessment were selected and they will be assessed for strength in the following chapter.

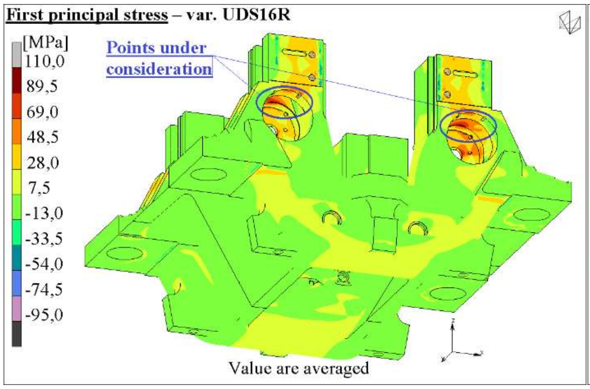


Fig. 6: The first principal stress for the loading var. UDS16R.

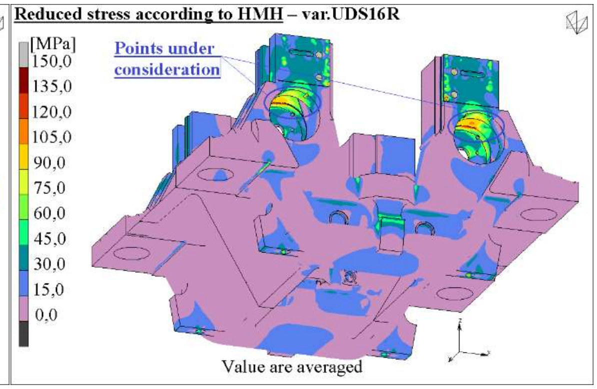


Fig. 7: Reduced stress according to HMH for the loading var. UDS16R.

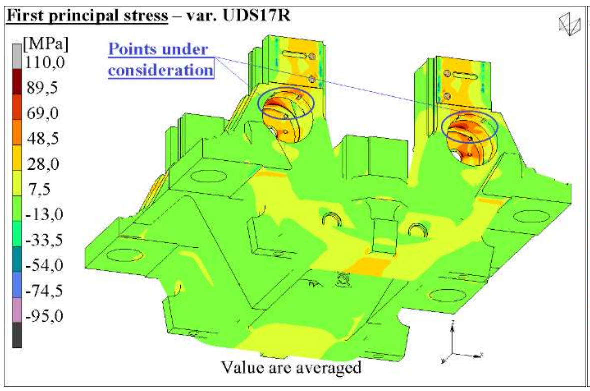


Fig. 8: The first principal stress for the loading var. UDS17R.

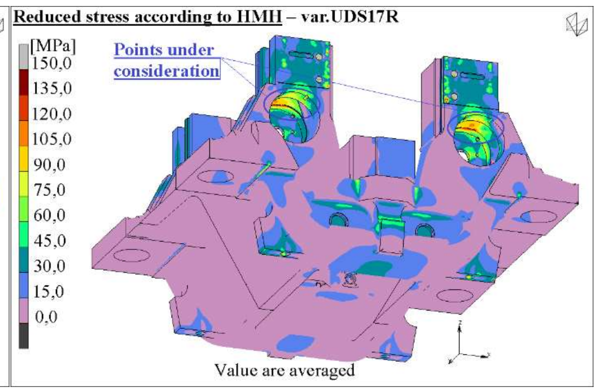


Fig. 9: Reduced stress according to HMH for the loading var. UDS17R.

4. Strength Assessment

Two locations (KM1, KM2) were selected from the results of the flexibility calculation (by the Marc Mentat 2023.3 program) for assessment. The SKALA program assessed the possibility of ductile, fatigue and sudden fracture, including crack propagation, at both locations. The SKALA program makes full use of the results of the elasticity solution in the linear field, and the generalized Neubér's principle is used to determine the plastic deformations necessary for the lifetime assessment.

Description of the points to be assessed:

a) KM1 - The tensile area of the recess of the M24 thread on the lower frame (Figs. 10 and 11) - (HS – UDS17R, DS – UDS15R) - taken for the higher upper state of load from UDS16R and UDS17R.

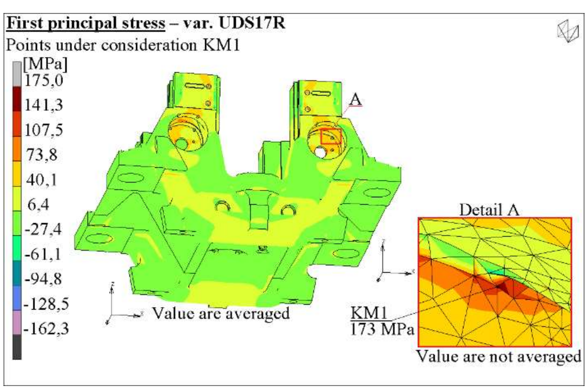


Fig. 10: First principal stress at the recess of the M24 thread for the loading var. UDS17R.

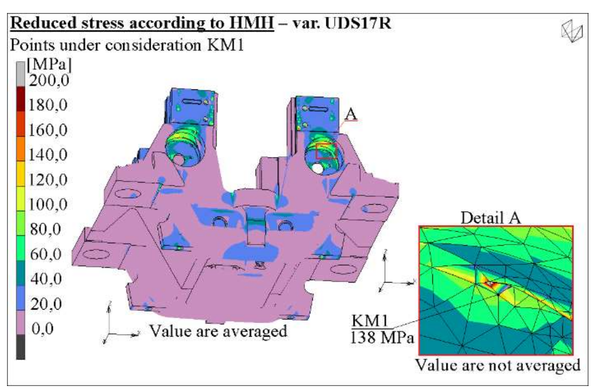


Fig. 11: Reduced stress at the recess of the M24 thread for the loading var. UDS17R.

b) KM2 - The tensile area of the M24 drilled-off thread on the lower frame (Figs. 12 and 13) - (HS – UDS16R, DS – UDS15R) - taken for the higher upper state of load from UDS16R and UDS17R.

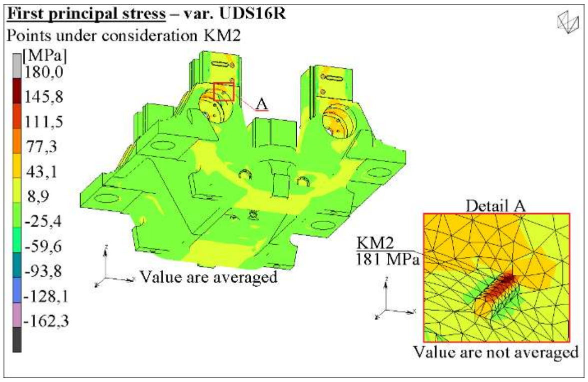


Fig. 12: The first principal stress of the M24 drilled-off thread for the loading var. UDS16R.

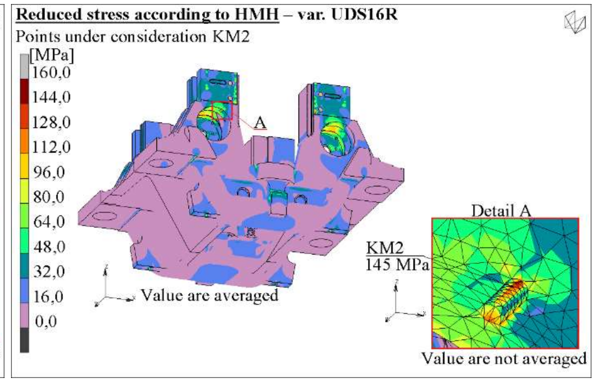


Fig. 13: Reduced stress of the M24 drilled-off thread for the loading var. UDS16R.

Brief overview of the strength evaluation results is shown in Tab. 1, where:

- ND - the number of permitted loading cycles,
- n_σ - the security against the occurrence of the limit state of fatigue (formation of a crack having conventional depth of 1 mm),
- n_{Rm}, n_{Rk} - the degree of safety against the ultimate strength and/or yield point in the block of ultimate state of ductile fracture,
- n_{sig}, n_{def} - the degree of safety against the strain of force or force plus deformation origin in the block of the limit state of sudden fracture,
- N_{kr}, (N_f) - the number of cycles with the crack propagation from the initial depth of 1 mm and/or from the depth L_p to the critical L_{kr} or functional (L_f) depth,
- L_k, L_{kr} - the critical depth of a crack at the critical point (node) L_k and/or L_{kr} during its propagation; when they are reached, a sudden fracture occurs in the critical cross-section,
- L_f - functionally permissible crack depth.

Variants of calculation	Point under consideration	Ductile fracture		Fatigue	Sudden fracture		Crack propagation	
		n_{Rm} [-]	n_{Rk} [-]	N_D [cycle] n_σ [-]	n_{sig} [-] n_{def} [-]	L_k [mm]	N_{kr} [cycle] (N_f [cycle])	L_{kr} [mm] (L_f [mm])
	Material 42 2712.5 (R_m = 500 MPa, R_e = 280 MPa)							
UDS17R/ UDS15R	KM1	Satisfactory 2.1	1.3	>1.00E7 2.419	3.710 3.530	10.0	- (110E6)	- (15)
UDS16R/ UDS15R	KM2	Satisfactory 2.1	1.3	>1.00E7 3.108	5.512 3.418	9.25	- (12.2E6)	- (10)

Tab. 1: Strength evaluation results for the assessed points.

5. Conclusions

According to the results of the elasticity and strength calculation of the design changes of the DUO rolling mill, it can be stated that, for the specified maximum operating loads and the above-mentioned materials, the specified design variant with pressing-on the bushings in the rolling mill meets the usually required safety limit states of both ductile and sudden fracture at assessed points KM1 and KM2 with sufficient reserve. Furthermore, for the specified maximum possible operating cyclic loads and the above-mentioned materials, the specified design variant with pressing-on the bushings in the rolling mill meets the limit state of fatigue (N_D > 1.0E7 cycles - permanent life) with sufficient reserve at the assessed points KM1 and KM2 from the point of view of usually required safety. The design revision can be used.

References

Pospíšil, B. (1976) *Evaluation of strength and durability of machine components*. ČVTS Praha (in Czech).