Topological Optimization of Machine Elements with Numerical Methods in Advanced MES Systems

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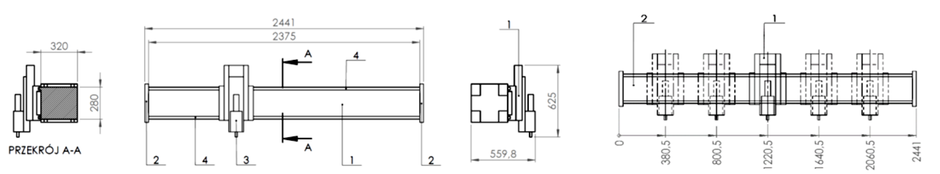
Abstract. This article concerns the application of topological optimization with numerical methods in the ABAQUS system of machine parts on the example of a laser cutter gate. The gate structure was optimized with the initial mass of 566 kg, assuming that the gate deflection is less than the permissible displacements and the reduced stress are lower than the allowable stresses. It has been shown that the optimal construction of the gate has a mass of 28.1 kg. In addition, the new gate can be made from one sheet of sheet metal using a simple laser cutting method.

INTRODUCTION

The article concerns the application of topological optimization [1-5] on the example of a machine gate used for laser sheet metal processing. The gate is an element of the working machine, where due to the high dynamics of work, its mass has a direct impact on work efficiency. For the preliminary analysis, the cubic parallel beam presented in Fig. 1a, made of steel 1.0038, weighing 566 kg, was used. Five extreme positions of the laser head on the gate were assumed for calculations (Fig. 1b).



(a) (b)

FIGURE 1. View of the laser cutter's gate system (a) and the extreme position of the laser head (b): 1-axis linear guide assembly, 2-intermediate X-axis, 3-laser head, 4-axis Y-linear guide

TOPOLOGY OPTIMIZATION

The numerical application for topological optimization was developed in the ABAQUS program. The method Solid Isotropic Material with Penalisation (SIMP) [5] was used.

The following material values have been adopted: Young's modulus E=215 GPa, Poisson's ratio v=0,28, tensile strength Rm=1900 MPa, yield stress Re=350 MPa, minimum elongation A= 14%. The object was discretized with Ne = 100611 finite elements type C3D10M (*tetrahedron*). At every step, the structure is loaded with acceleration 3g=29,42 $m \cdot s^{-2}$ and for the next step, the reverse acceleration -3g=-29,42 $m \cdot s^{-2}$. The next interaction was the naturally occurring acceleration of the Earth 1g=9,807 $m \cdot s^{-2}$. In addition, boundary conditions (3) and (4) for displacements have been introduced (Fig. 2).

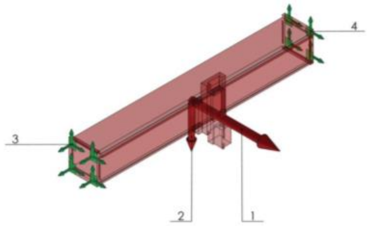
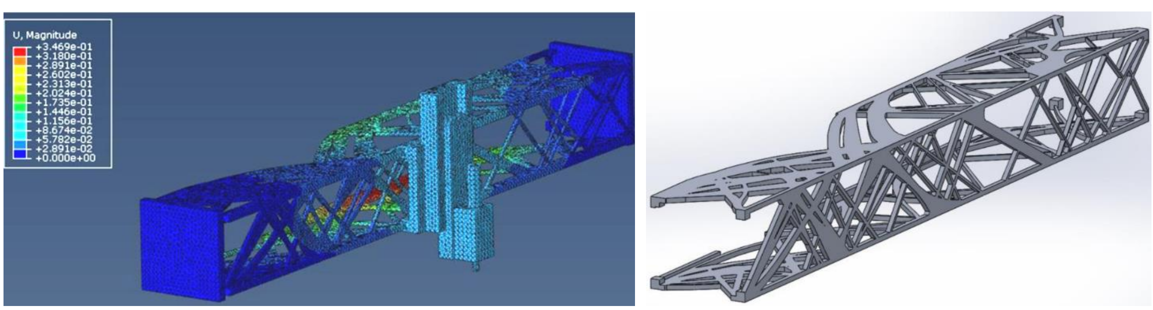


FIGURE 2. Types of load and mounting of the system: 1 - acceleration 3g, 2 - gravity acceleration 1g, 3- type of fixing the left intermediate plate X, 4 - type of fixing the right intermediate plate X

In order to optimize the topology, the minimum thickness of the rectangular bar area was determined in order to obtain material continuity. According to the assumptions, the gate will be made of sheet metal cut with a laser cutter. This limitation guarantees the minimum size of the area in which the optimization creates trusses. The minimum size f=15 mm of the area was entered in the option Edit Geometrical restriction, Minimum phickness and avoids thin trusses that can be difficult to make. To prevent structural discontinuity, the optimizer module tries to avoid creating thin trusses in regions where specific conditions apply.

RESULTS

After the optimization process, the gate weight decreased to 28.1 kg (Fig. 3), which is 4.96% of the initial value equal to 566 kg. The similar structural design of the gate currently used in industry has a mass of 41 kg.



(a) (b)

FIGURE 3. Displacement values in the most inconvenient load case for step 3g (a) and a three-dimensional solid model of the gate as a truss obtained after topological optimization (b)

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