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ANALYSIS OF THE DEFORMATIONS IN „DELTA WIRED 3D PRINTER"

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Abstract: With the use of 3D printing technology, layer by layer extrusion is possible printing of concrete building objects, but printers represent a large size and mobility limited metal construction. In a new 3D printer construction, called "Delta Wired 3D Printer", the large stress created from bending moments are transformed in normal stress from tension. After we have calculates the loads on individual elements we can determine their dimensions and deformation. The loads are different in any point of workspace coordinate system this creation of different deflections for any point, which will increases dimension errors of printed object. In this paper are theoretically calculated total extruder deflections as a function of tensile in wires, bending in pillars taking into account changes in forces for any coordinate points.
Keywords: delta wired 3d printer, printing of building objects, mobile 3d printer, reconstructions of 3d printer

INTRODUCTION

By using Cramer's formulas in article [1] for solving a system of linear equations corresponding to the balance of the mechanical system is achieved by clearly defining efforts in supporting ropes and their change depending on the coordinates of the wires intersection point. These decisions represent the initial data to calculate deformations in the individual elements and total deformation in extruder. The scheme of „Delta Wired 3d Printer" is represented in Figure1.

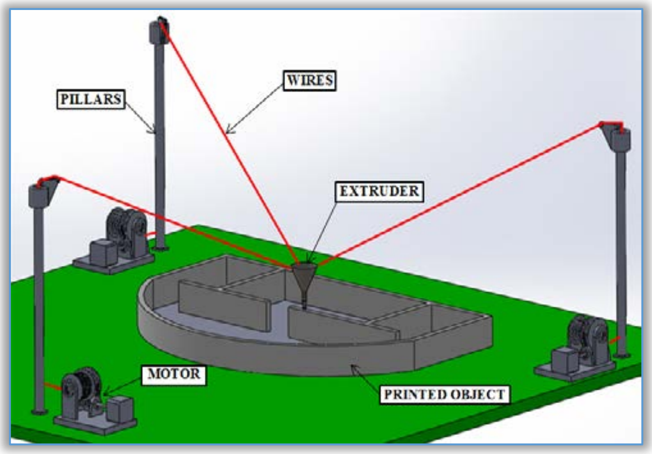


Figure 1. Conceptual design of "delta 3D wired printer" [2]

BODY OF THE PAPER

In order to determine the deflection of the extruder it is necessary to consider the following calculation scheme, shown in Figure 2.

With next equations we can determine of distortion bending in pillars [3], where:

$$\Delta la_{bend} = \frac{Fa.\cos(\alpha_Z).d_a^{\,3}}{3.E.I} = \frac{K_{Fa}.Q.\cos(\alpha_Z).d_a^{\,3}}{3.E.I};$$

$$\Delta lb_{bend.} = \frac{Fb.\cos(\beta_Z).d_b^{\,3}}{3.E.I} = \frac{K_{Fb}.Q.\cos(\beta_Z).d_b^{\,3}}{3.E.I};$$

$$\Delta lc_{bend} = \frac{Fc.\cos(\gamma_Z).d_c^{\,3}}{3.E.I} = \frac{K_{Fc}.Q.\cos(\gamma_Z).d_c^{\,3}}{3.E.I}; \quad (1)$$

where: E – modulus of elasticity for pillars material, Pa; I –moment of inertia for cross section of pillars, m^4; Fa, Fb and Fc – tensile force in wires A, B and C, N; Q – weight of extruder, kgf; K_{Fa}, K_{Fb} and K_{Fc} – coefficients define force value; α_Z, β_Z and γ_Z – angles between horizontal plane and wires, deg;

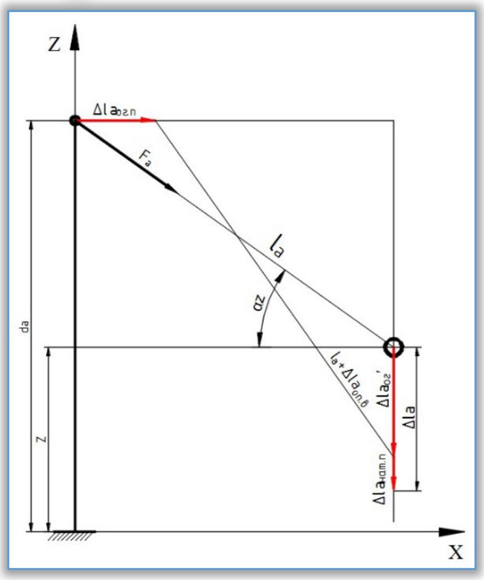


Figure 2. Estimated scheme for determining the deformations of one of the bearing clones
Δla_{bend} – distortion by bending pillar A, m; $\Delta la_{bend}'$ – deflection of extruder from bending of pillar A, m;
Δla_{comp} – deformation of compression in pillarA, m; $\Delta la_{tens.w}$ – deformation from tensile in wire of pillar A, m;
la – length of wire in clone A, m; Δla – total deflection of extruder, m; d_a – height of pillar A, m.

For determination of tensile deformation in wires are used the following equations [4]:

$$\Delta la_{tens.w} = \frac{Fa.la}{E_w.A_w} = \frac{K_{Fa}.Q.la}{E_w.A_w};$$

$$\Delta lb_{tens.w} = \frac{Fb.lb}{E_w.A_w} = \frac{K_{Fb}.Q.lb}{E_w.A_w};$$

$$\Delta lc_{tens.w} = \frac{Fc.lc}{E_w.A_w} = \frac{K_{Fc}.Q.lc}{E_w.A_w} \qquad (2)$$

where: E_w – Modulus of elasticity for wires material, Pa; A_w – Cross section area for wires, m²;
By analogy to deformations of compression in the pillars can write:

$$\Delta la_{comp} = \frac{Fa.\sin(\alpha_Z).d_a}{E.A_p} = \frac{K_{Fa}.Q.\sin(\alpha_Z).d_a}{E.A_p};$$

$$\Delta lb_{comp} = \frac{Fb.\sin(\beta_Z).d_b}{E.A_p} = \frac{K_{Fb}.Q.\sin(\beta_Z).d_b}{E.A_p};$$

$$\Delta lc_{comp} = \frac{Fc.\sin(\gamma_Z).d_c}{E.A_p} = \frac{K_{Fc}.Q.\sin(\gamma_Z).d_c}{E.A_p}; \qquad (3)$$

where: A_p – Cross section area for pillars, m²;
If we consider the two right triangles in Figure 2 and using the geometric relationships leads to the equation that for clone A was as follows:

$$\Delta la_{bend}' = \sqrt{(la + \Delta la_{tens.w})^2 - (la.\cos(\alpha_Z) - \Delta la_{bend})^2} - la.\sin(\alpha_Z) \qquad (4)$$

To the resulting deformation taking into account the deflection in pillars and tension in the wire may be added the deformation of compression in pillar, equation for full deformation in clone A that will occur as a result of the force Fa is:

$$\Delta la = \Delta la_{bend}' + \Delta la_{comp} = \sqrt{(la + \Delta la_{tens.w})^2 - (la.\cos(\alpha_Z) - \Delta la_{bend})^2} - la.\sin(\alpha_Z) + \Delta la_{comp} \qquad (5)$$

For clones B and C the equations are:

$$\Delta lb = \Delta lb_{bend}' + \Delta lb_{comp} = \sqrt{(lb + \Delta lb_{tens.w})^2 - (lb.\cos(\beta_Z) - \Delta lb_{bend})^2} - lb.\sin(\beta_Z) + \Delta lb_{comp} \qquad (6)$$

$$\Delta lc = \Delta lc_{bend}' + \Delta lc_{comp} = \sqrt{(lc + \Delta lc_{tens.w})^2 - (lc.\cos(\gamma_Z) - \Delta lc_{bend})^2} - lc.\sin(\gamma_Z) + \Delta lc_{comp} \qquad (7)$$

For total deformation obtained as a result of the forces in the three different clones using the principle of superposition can be written:

$$\Delta l = \Delta la + \Delta lb + \Delta lc \qquad (8)$$

To make the moment of inertia of the cross section of the pillars same for each direction of bending is required, it is a circle or tube wherein:

» for tube: $I_{px} = I_{py} = \frac{\pi(D_p^4 - d_p^4)}{64} = const;$

» for round section: $I_{px} = I_{py} = \frac{\pi D_p^4}{32} = const;$

In addition is necessary the cross-sections of the pillars must be uniform along the entire length of the tube to be valid relationship for determining the bending deformation. The values of the modulus of elasticity and the cross sections of the wires and the pillars are also constants, which results in the following functional equation of the full deflection of the deflection of the load:

$$\Delta l = \Delta la + \Delta lb + \Delta lc = f(la;Fa;\square_Z;d_a) + f(lb;Fb;\beta_Z;d_b) + f(lc;Fc;\gamma_Z;d_c) \qquad (9)$$

where for Δla, Δlb and Δlc we can write:

$$\Delta la=\sqrt{\left(la+\frac{Fa.la}{E_w.A_w}\right)^2-\left(la.\cos(\alpha_Z)-\frac{K_{Fa}.Q.\cos(\alpha_Z).d_a{}^3}{3.E.I}\right)^2} \quad (10)$$
$$-la.\sin(\alpha_Z)+\frac{K_{Fa}.Q.\sin(\alpha_Z).d_a}{E.A_p}$$

$$\Delta lb=\sqrt{\left(lb+\frac{Fb.lb}{E_w.A_w}\right)^2-\left(lb.\cos(\beta_Z)-\frac{K_{Fb}.Q.\cos(\beta_Z).d_b{}^3}{3.E.I}\right)^2} \quad (11)$$
$$-lb.\sin(\beta_Z)+\frac{K_{Fb}.Q.\sin(\beta_Z).d_b}{E.A_p}$$

$$\Delta lc=\sqrt{\left(lc+\frac{Fc.lc}{E_w.A_w}\right)^2-\left(lc.\cos(\gamma_Z)-\frac{K_{Fc}.Q.\cos(\gamma_Z).d_c{}^3}{3.E.I}\right)^2} \quad (12)$$
$$-lc.\sin(\gamma_Z)+\frac{K_{Fc}.Q.\sin(\gamma_Z).d_c}{E.A_p}$$

For determining the angles and forces depending on the location of the columns and the coordinates of the intersection to the coordinate system used dependencies [1].

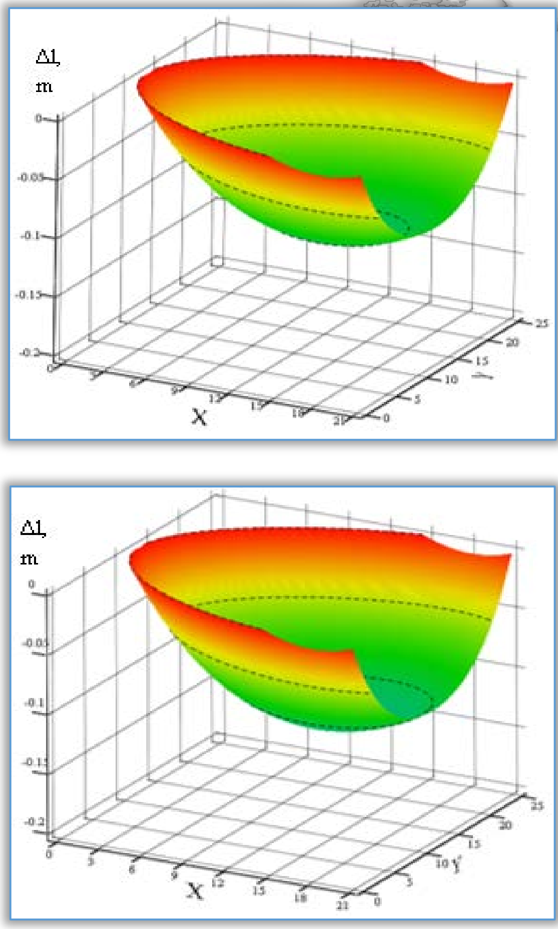


Figure 3a-b. Amendment of total deflection Δl, m of the load depending on the coordinates X and Y, at: a) Z=0 m; b) Z=0,25 m;

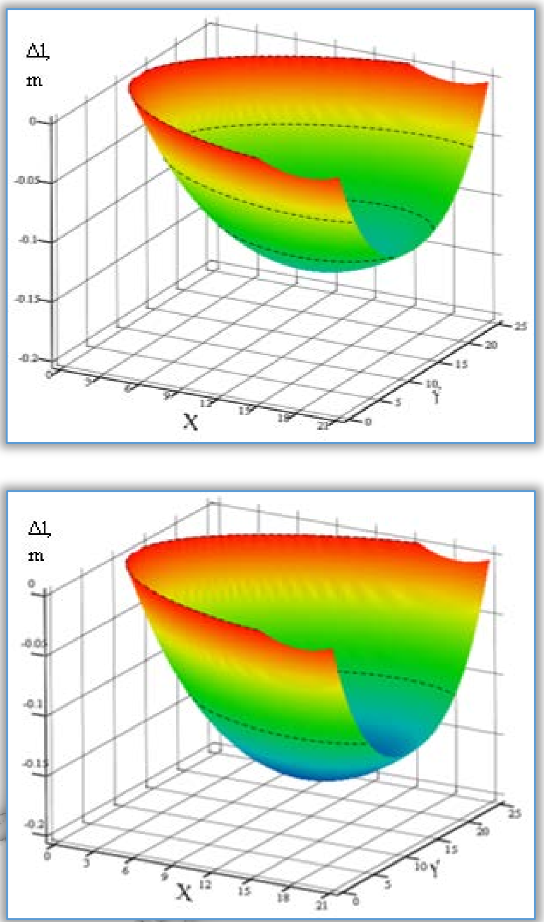
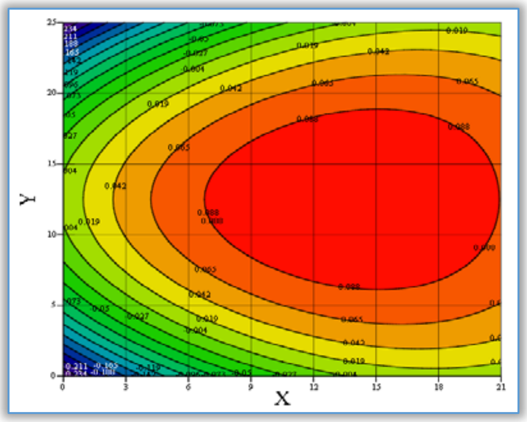


Figure 3c-d. Amendment of total deflection Δl, m of the load depending on the coordinates X and Y, at: c) Z=0,5 m; d) Z=1 m, surface plot;

As seen from dependence deflection of the load is influenced by: its size - expressed through the forces Fa, Fb and Fc; the location of the intersection of the wires - expressed by the coordinates X, Y and Z; angles α_Z, β_Z and γ_Z dependent and the height of the the pillars da, db and dc, and several constants taking into account the mechanical properties of the materials and the geometrical characteristics of their cross sections.

For visualization of the results obtained are shown several plots of the deformations depending on the various factors affecting to them.



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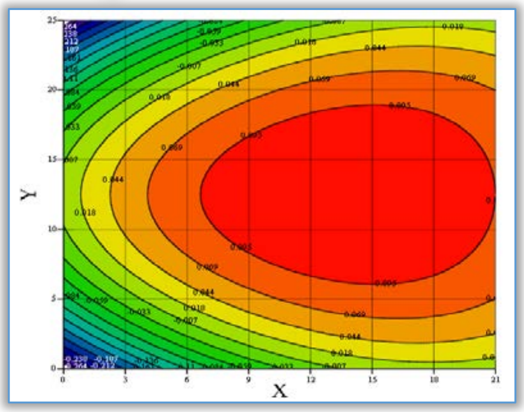
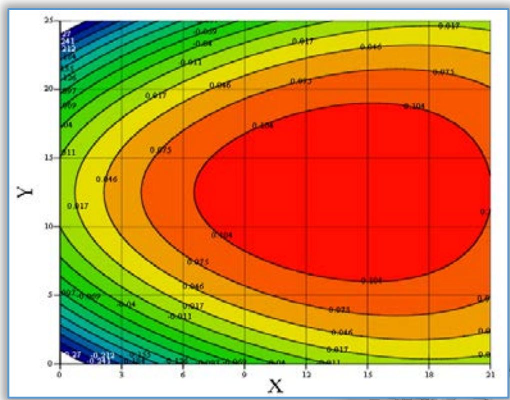


b)



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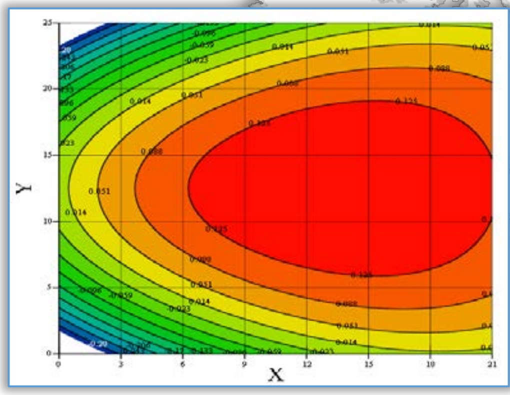
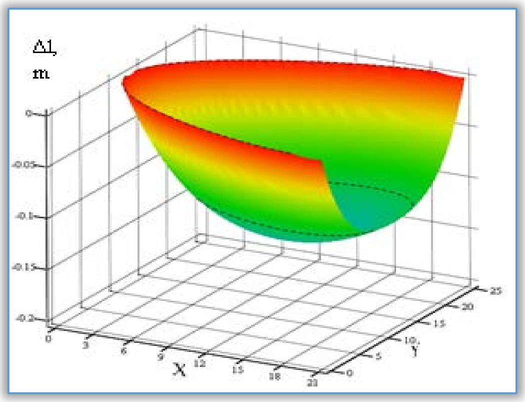
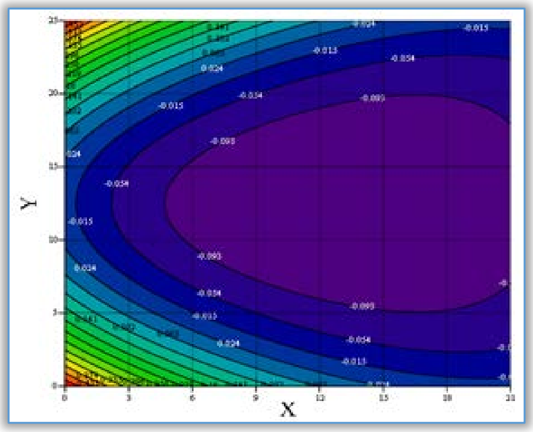


d)

Figure 4. Amendment of total deflection Δl, m of the load depending on the coordinates X and Y, at: a) Z=0 m; b) Z=0,25 m; c) Z=0,5 m; d) Z=1 m, contour plot;



a)



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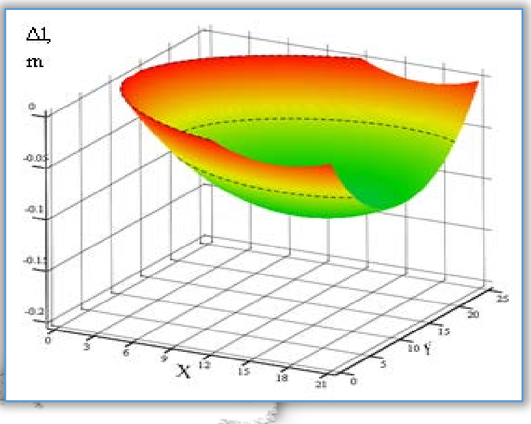

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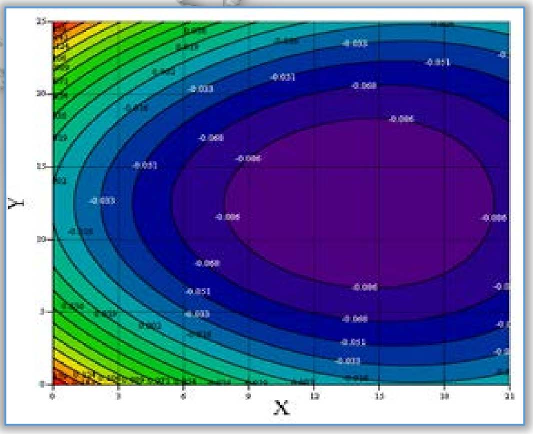

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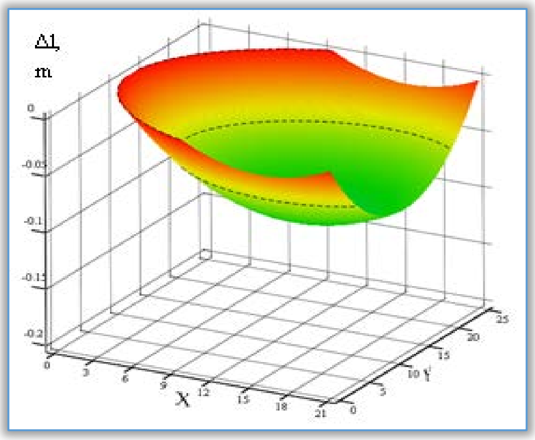

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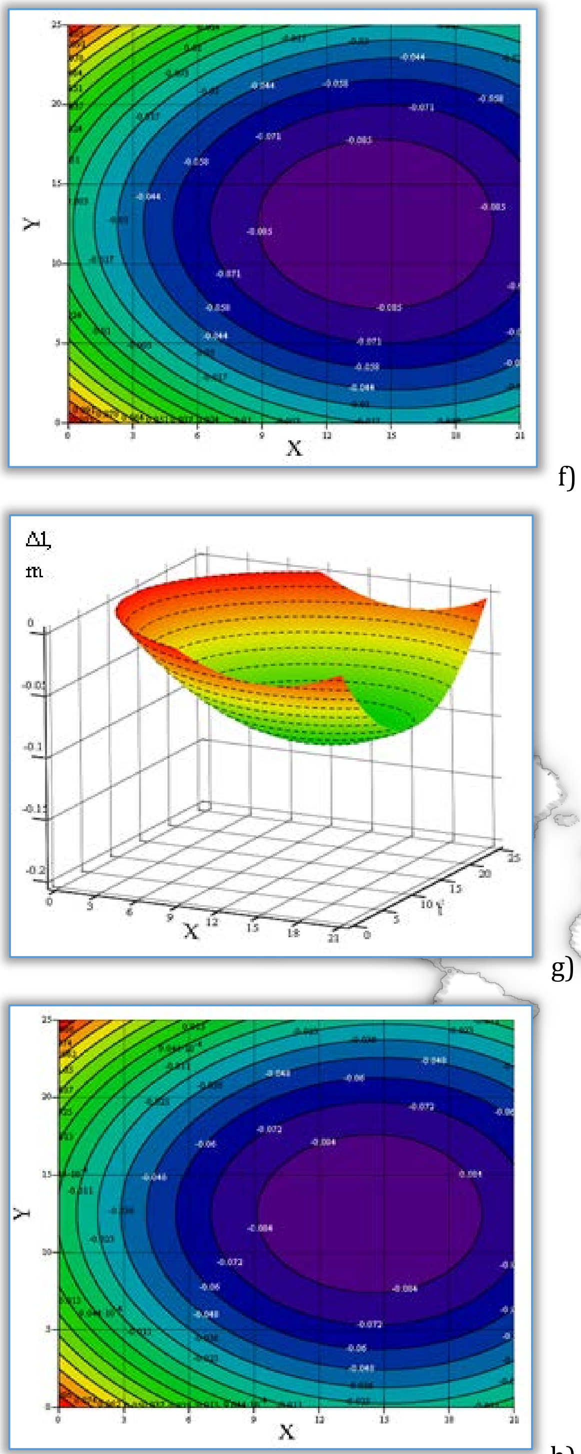


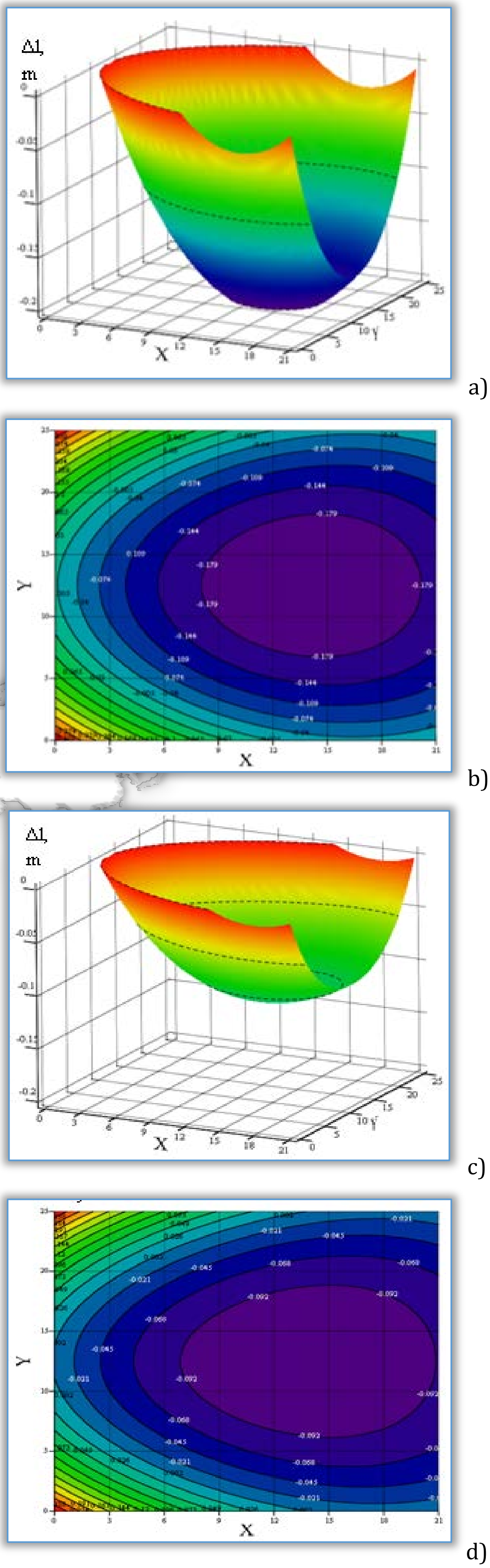
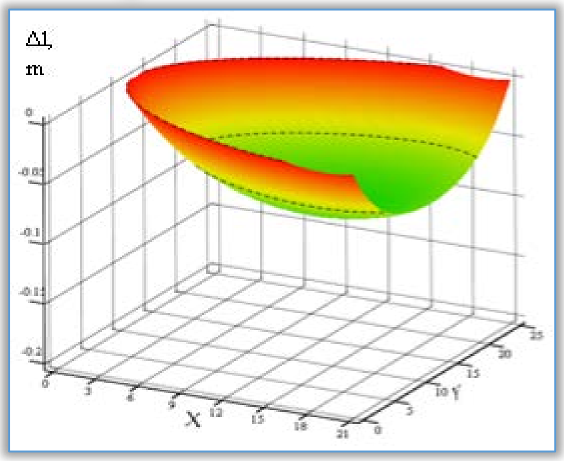


Figure 5. Amendment of total deflection Δl, m of the load depending on the coordinates X and Y, at wires diameter: a-b) d_w=10 mm; c-d) d_w=20 mm; e-f) d_w=30 mm; g-h) d_w=40 mm, surface and contour plot;



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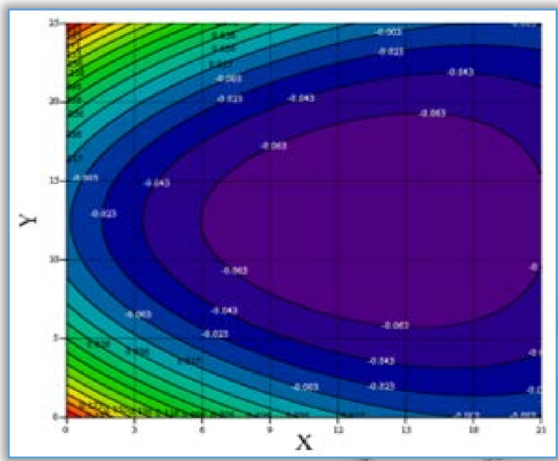

f)

Figure 6. Amendment of total deflection Δl, m of the load depending on the coordinates X and Y, at pillars moment of inertia $I_{px} = I_{px}$: a-b) 3000 mm^4; c-d) 6000 mm^4; e-f) 9000 mm^4, surface and contour plot;

CONCLUSIONS

From the analysis of the results can be made the following important findings and conclusions:

– The deflection of the load (extruder) depends on: the structural parameters of the individual elements – height of the pillars; the material of wires and the pillars; geometrical characteristics of the cross sections of the wires and the pillars; coordinates of the intersection between the three wires of working space;
– The increase of the diameter of the supporting rope (wires) reduces the deflection of the load visible in Figure 5;
– The increasing of moment of inertia for the pillars cross section of leads to a reduction of deflection of the extruder Figure 6;
– For increasing the coordinate Z (the distance between the intersection point between wires and the horizontal plane) have increasing deflection of load;
– If the intersection point of the wires moves by contour graphics trajectory in the workspace showing of Figure 3 to the Figure 6, deflection will be equally. The extruder will move in one plane in the event that the weight of the load Q is constant.

For future studies should be determined the weight of the extruder, weight required for a transition mixture which will form the design calculation of the diameter of the wires and the size of the pillars.

References

[1.] Vasilev, T., Sabeva V., Ivanova, E., Distribution Of Force Load In Wires Of „Delta Wired 3D Printer", Mechanics, Transport, Communications - Academic Journal, 1/2017, p. VII.1-VII.6
[2.] Vasilev, T., Optimization of Construction of 3D Printer For Building Objects, Mechanical Engineering & Science, Year XII, №1, 2017, p.105-109
[3.] Budynas, R. G., Nisbett,J. K., Shigley's Mechanical Engineering Design, Ninth Edition, Budynas Nisbett, 2008
[4.] Shigley, J. E.,Mischke, C. R., standard handbook of machine design, Second Edition, McGraw-Hill, 1996
[5.] Milcov, V., Съпротивление на материалите (теория, задачи и софтуер), Второ коригирано и актуализирано издание, Технически университет – Varna, 2008, 201 с.

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