SHAPE OPTIMIZATION USING A GENETIC ALGORITHM AND FINITE ELEMENT METHOD

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INTRODUCTION

- Genetic algorithm (GA) is an optimization technique based on the principles of natural selection
- GA allows a population composed of many individuals to evolve under specified selection rules to fitness function (criterion)
- Deals with a large number of variables

OPTIMIZATION OF SHAPE

- Decrease of stress or decrease of strain without mass grow
- Increase lifetime of the parts
- Eventually decrease of mass without increasing stress or deformation

REQUIREMENTS

- Model – description of geometry
- Boundary condition, forces, contrains
- Fitness function - criterion
  - get due to FEM (FreeFem, Matlab, Marc-Mentat)

PARAMETERS SELECTION

- change geometry by modifying parameters
- parameter is coordinates of nodes
- thickeness of element
- curves – parameter is control point
  - for example bezier curves, spline, …

CANDIDATE SOLUTION

(called individuals or phenotypes)

- individuals formed from parameters
- number of parameters = size of individual
- each of individuals are rated by fitness function

POPULATION

- population formed from individuals
- ways to create first population
  - manually
  - randomly-generate in right intervals
  - tournament

HOW TO CREATE NEXT POPULATION

1) CROSSOVER

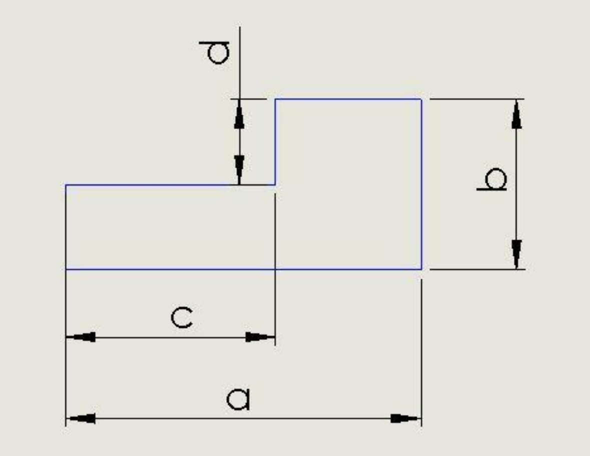
- recombination of individuals to create children
- stronger individuals have more children than the weakest one

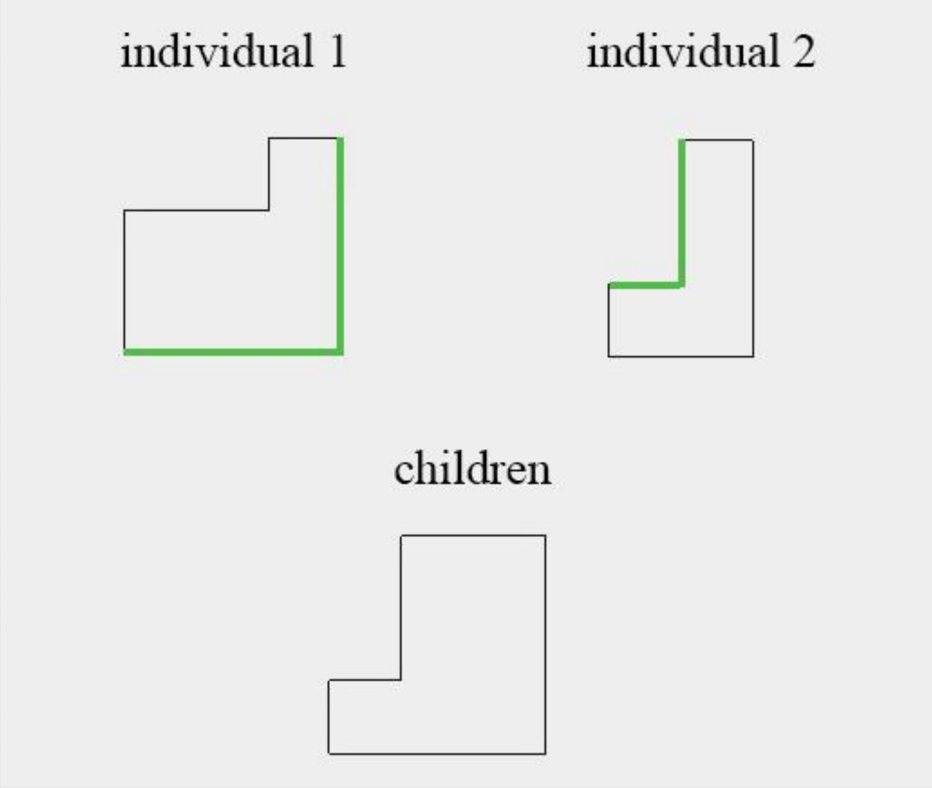
HOW TO CREATE NEXT POPULATION

1) CROSSOVER

example:

	a	b	c	d
ind. 1	3	3	2	1
ind. 2	2	3	1	2





LIMITS:

a > c
b > d

HOW TO CREATE NEXT POPULATION

2) MUTATION

- multiply by constant in interval:

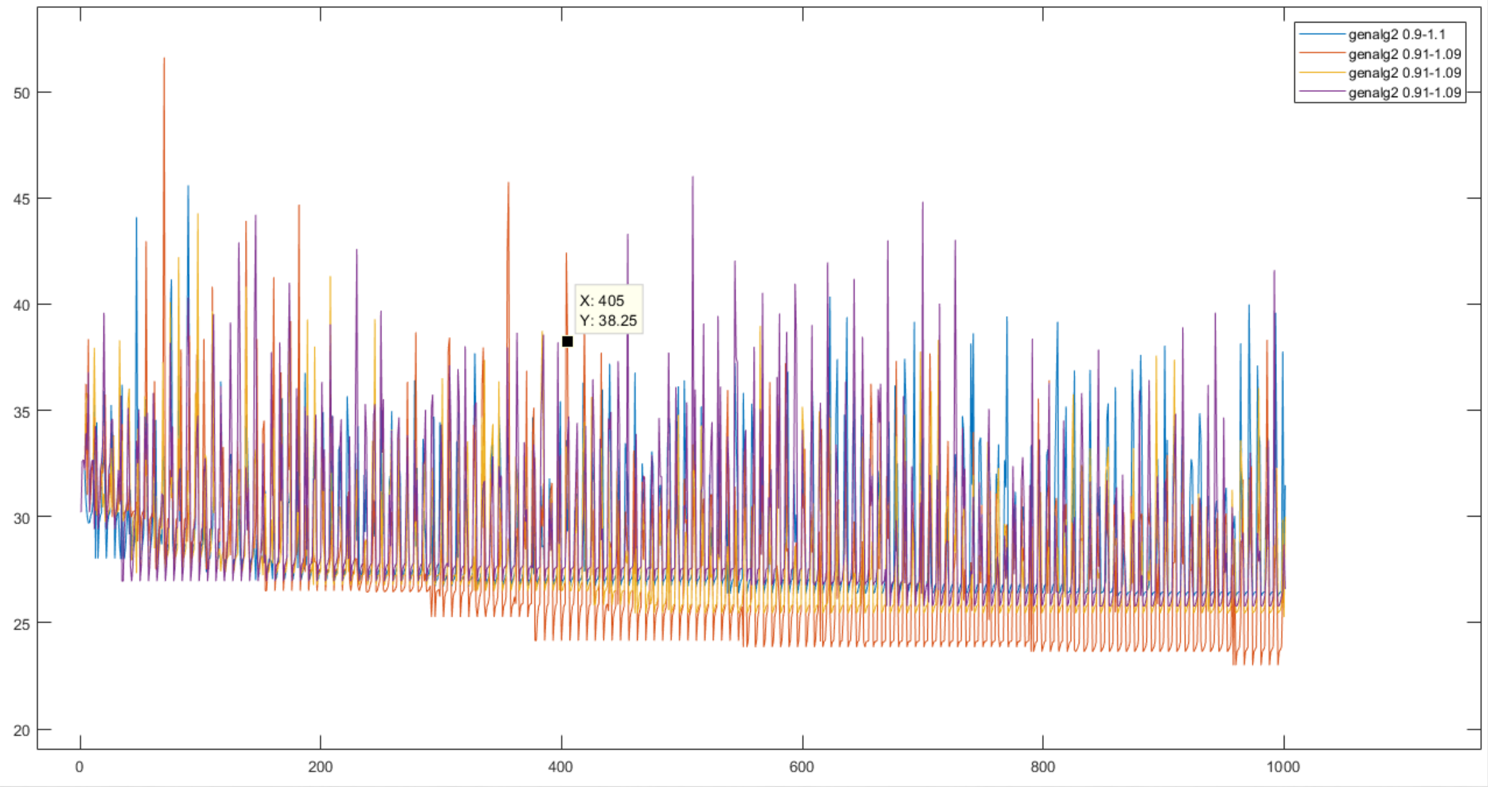
$$c = 1 \mp \frac{\Delta}{100}$$

$\Delta \ldots maximum\ of\ percent\ change$

HOW TO CREATE NEXT POPULATION

2) MUTATION

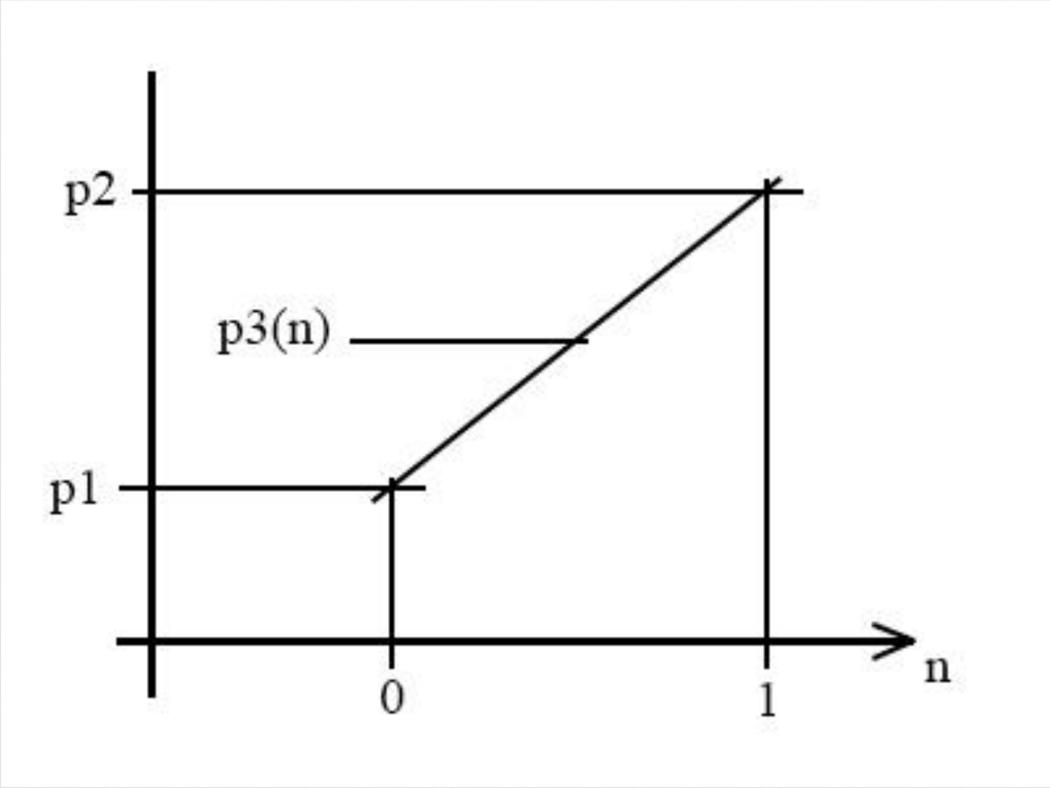
In this case Δ=9%



HOW TO CREATE NEXT POPULATION

2) MUTATION $$p_3(n) = p_2 \times n + p_1 \times (1 - n)$$

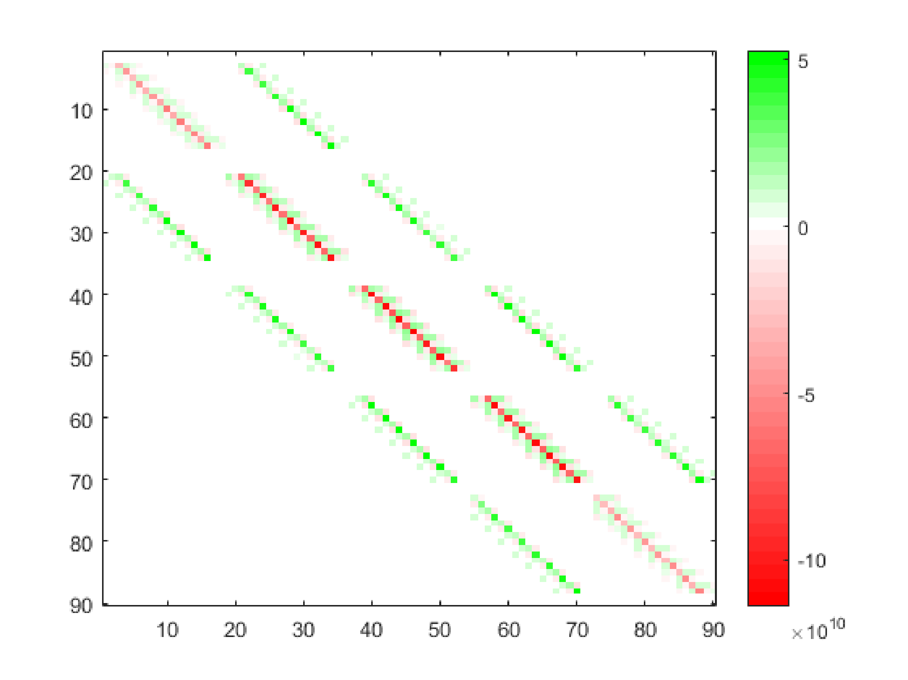
- combination of parameters:



WAYS TO SPEED UP ALGORITHM

- use properties of global stiffness matrix
- the most of elements are equal to zeros
- In Matlab we can use function SPARSE(MATRIX) to work just with non-zero elements

Example of Global stiffness matrix (just 45 nodes)



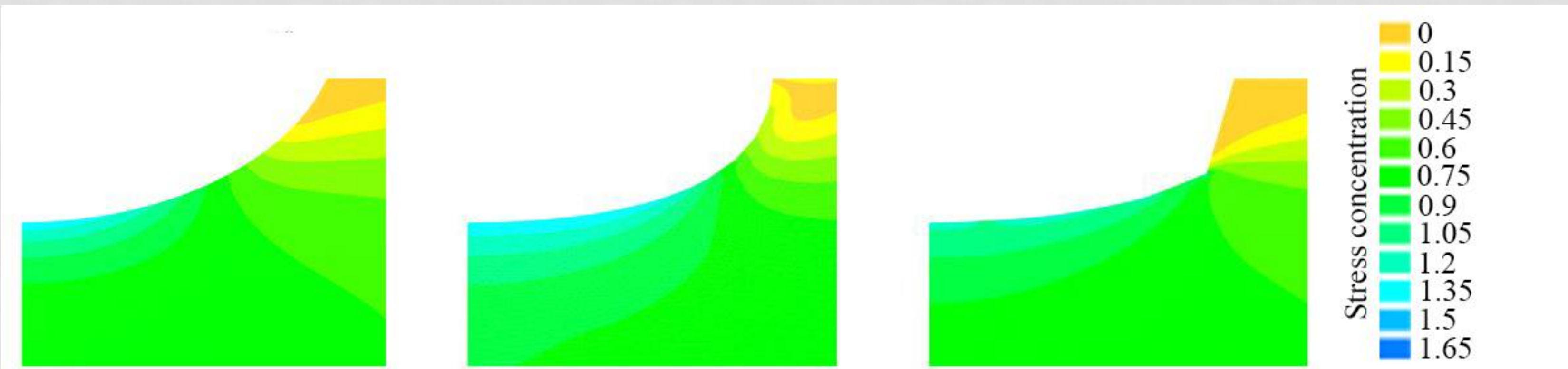
WAYS TO SPEED UP ALGORITHM

- In each iteration is stiffness matrix of element same, just multiply different volume (depends on thickness)
- We can prepare stiffness matrix of all elements and just multiply by volume (we change just thickness of elements) in each iteration

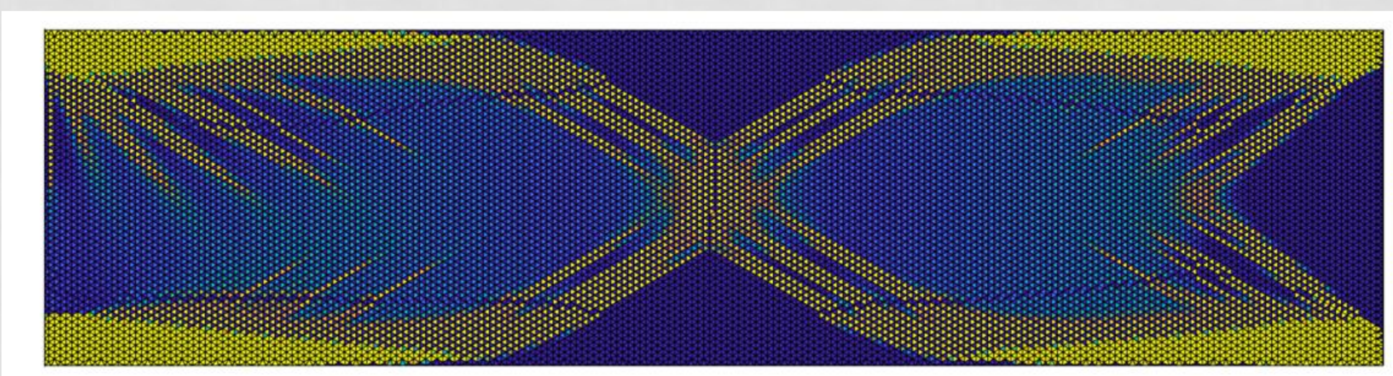
$$K = V \times (S^{-1})^T \times B^T \times E \times B \times S^{-1}$$

2 EXAMPLES OF USING GA OPTIMIZATION

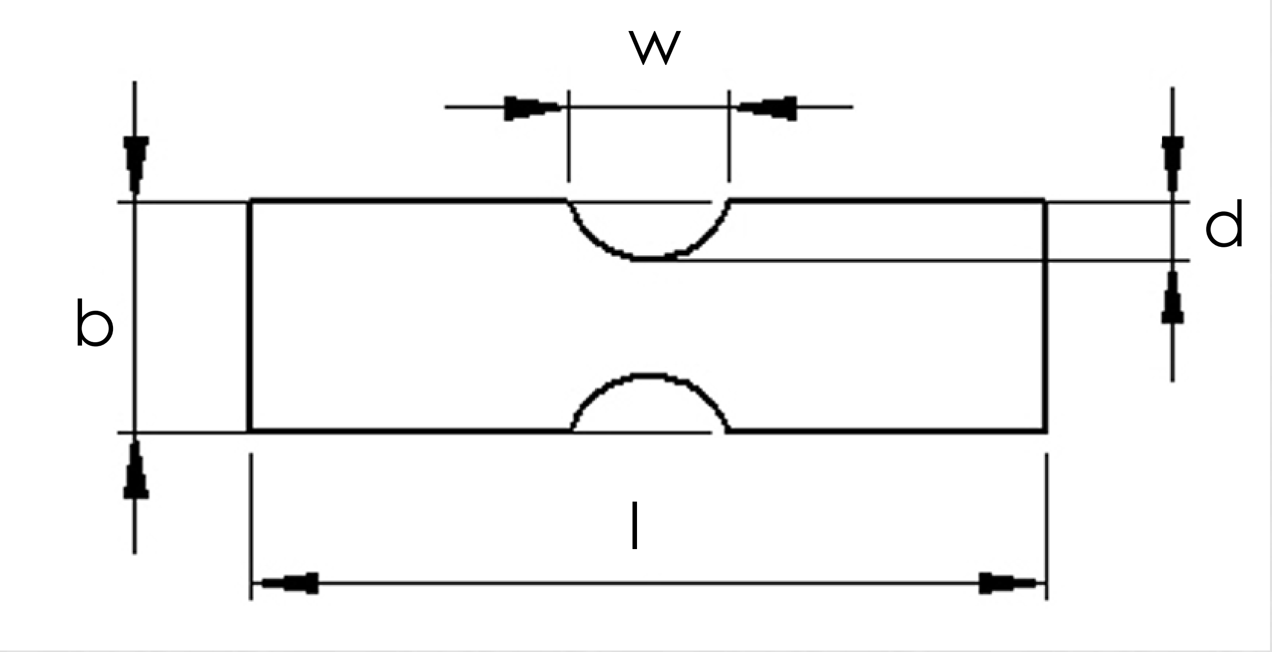
- Optimization of notch on shaft



- Mass distribution on beam

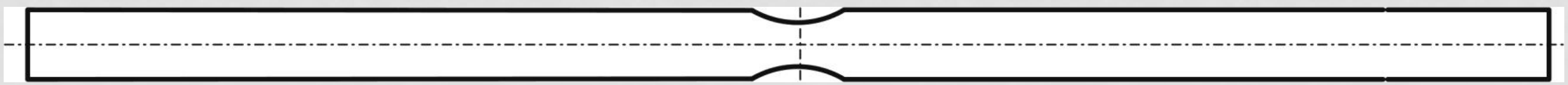


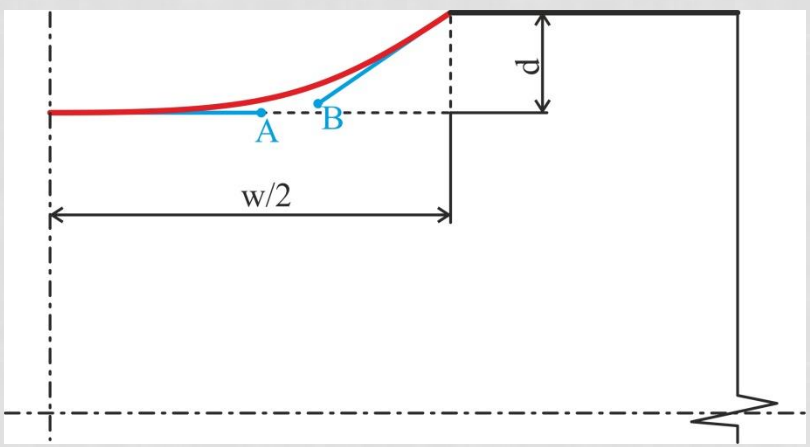
GEOMETRY OF SHAFT



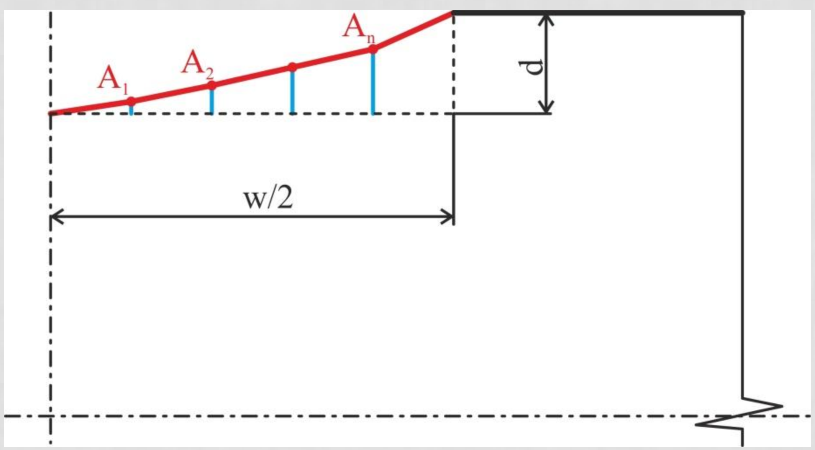
DESCRIPTION OF THE NOTCH GEOMETRY

- described by two different ways





Bezier curve



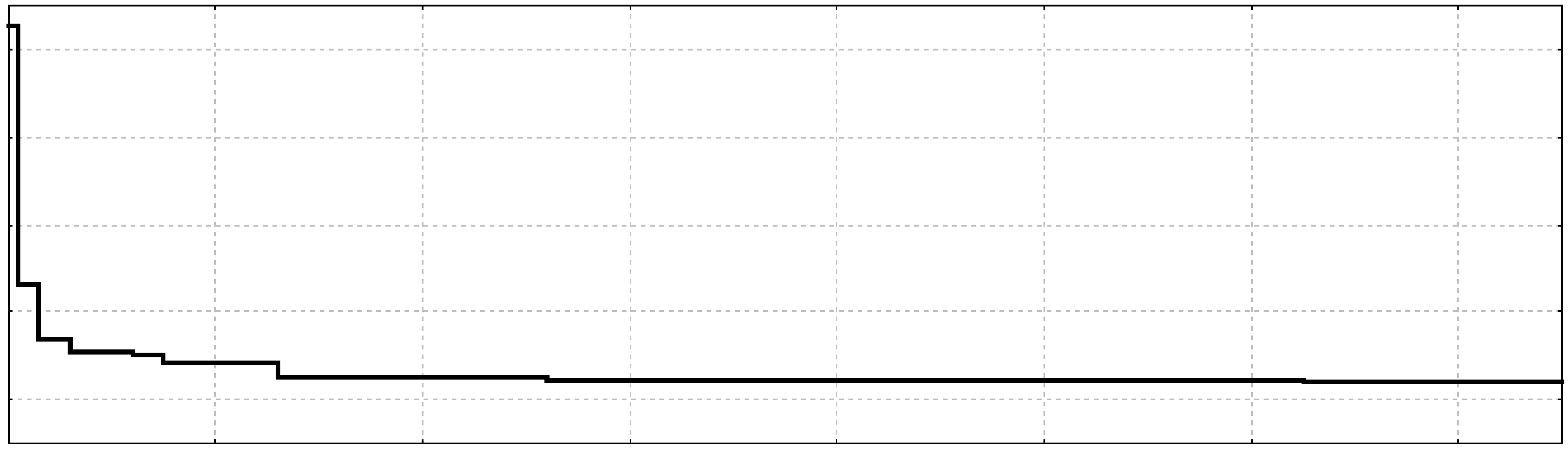
Polyline

FITNESS FUNCTION

- as optimization criterion was used max. equivalent stress (HMH) in part
- notch with circular shape is used as reference

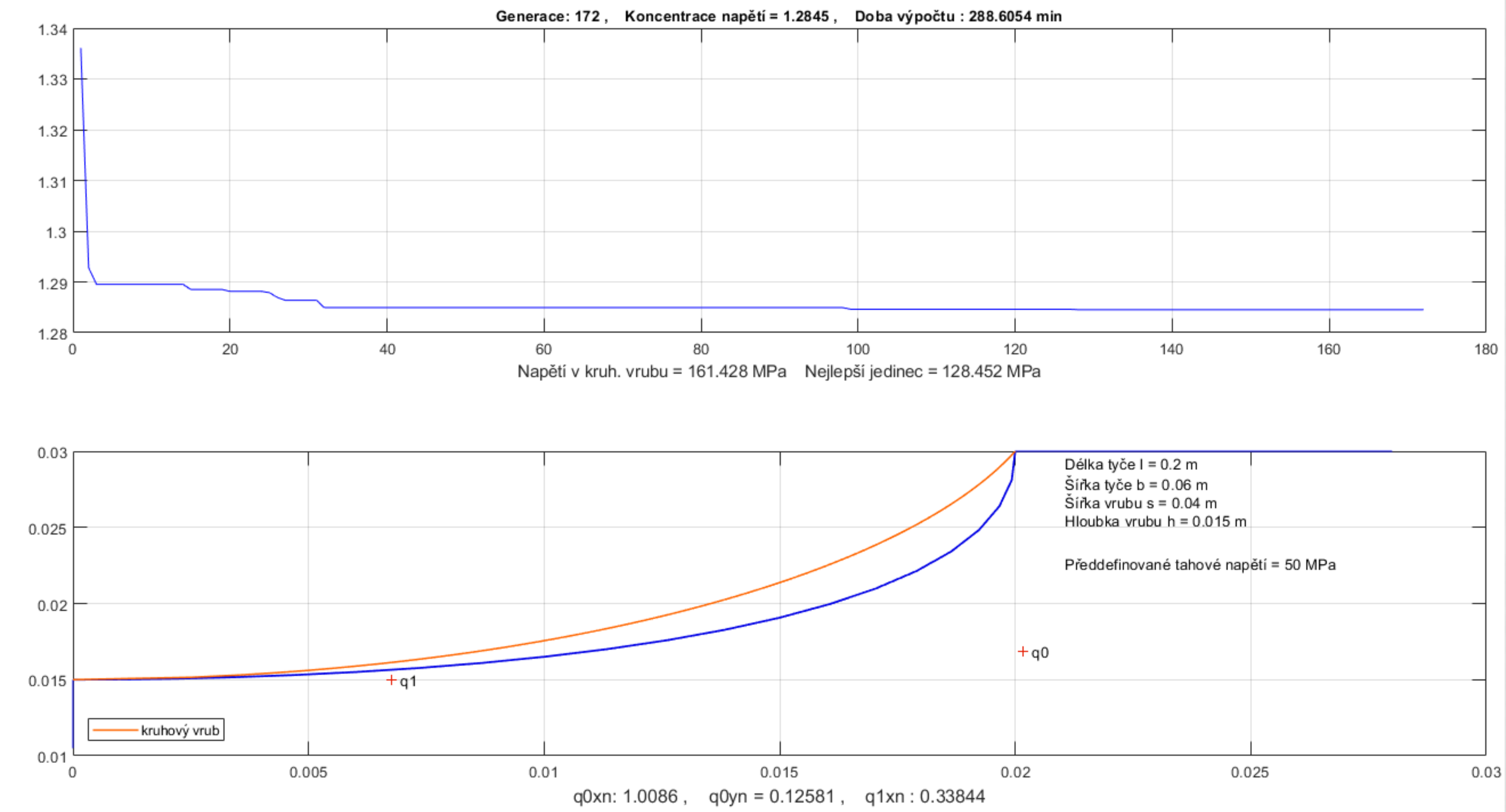
FITNESS FUNCTION

General process of fitness function

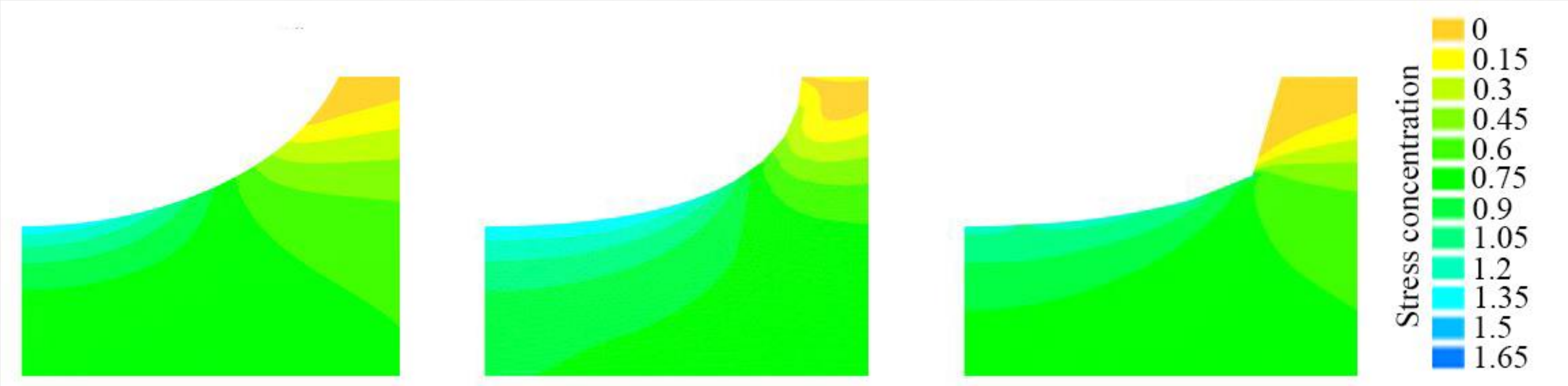


FITNESS FUNCTION

Process of fitness function, program made in MATLAB



COMPARE



circle notch

max. con. = 1.478

bezier notch

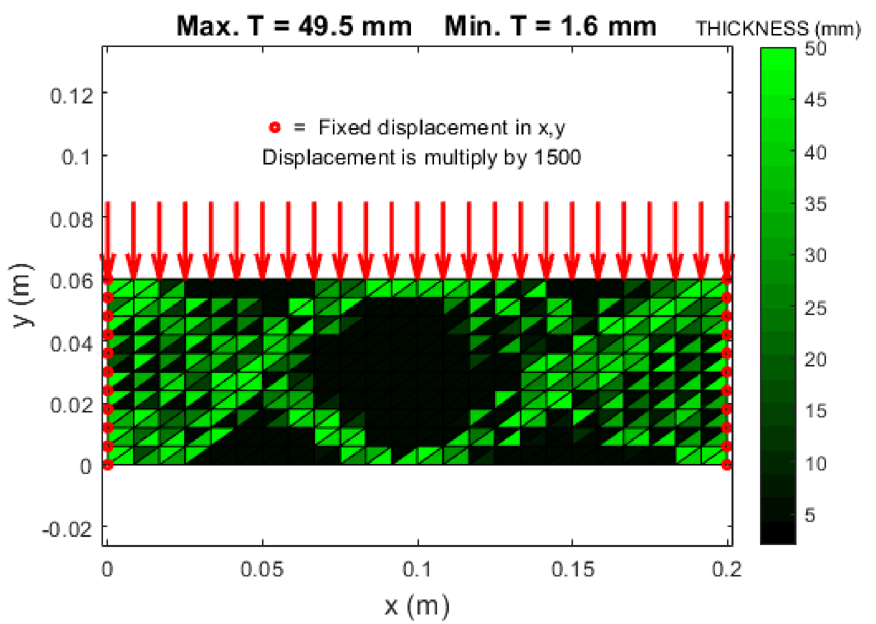
max. con. = 1.3

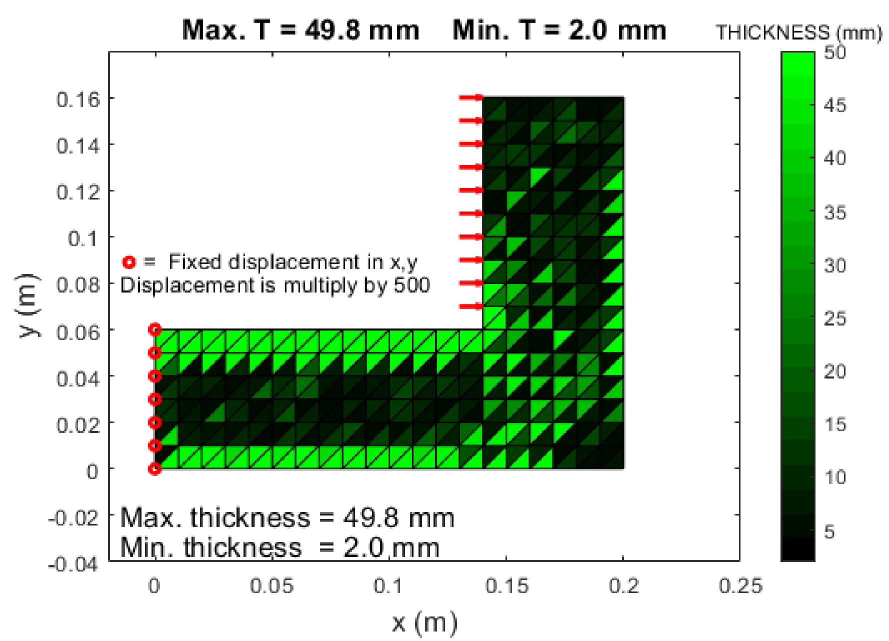
polyline undercut

max. con. = 1.36

DISTRIBUTION ON MASS

- second example of usign GA – bending segments of any shape





CONCLUSION

Genetic algorithm is useful and efficient for significant minimization of stress concentration or deformation of component at a specific location. This can be important for lifetime of parts. In this presentation is shown just two examples of using algorithm. But once we have a description of part geometry and loadcases, we can optimized shape of any parts.

Please don’t hesitate to interrupt me if you have any questions.

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THANKS FOR YOUR ATTENTION