# X SICEL 2021

## Transición energética en la 4ta revolución industrial


Universidad Tecnológica de Pereira

UNIVERSIDAD NACIONAL DE COLOMBIA

XSICEL 2021
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# Optimal Design of a Helical Spring by Using a Genetic Continuous Algorithm


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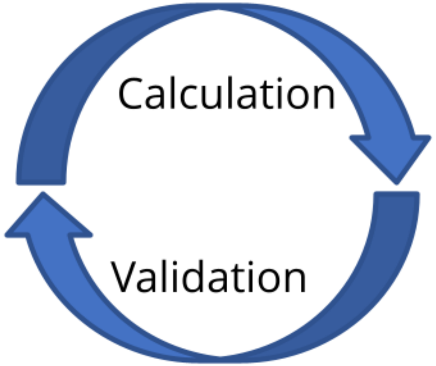
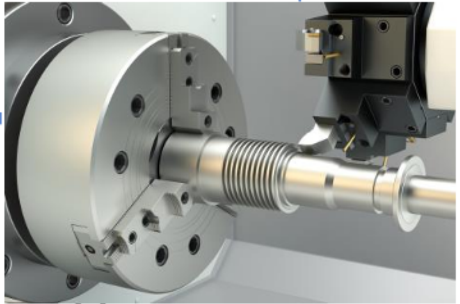
# I. Introduction

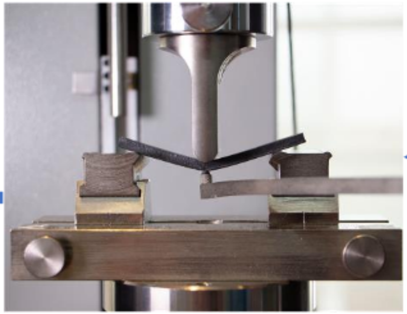
Physical requirement.

Idea formulation.



Many prototypes.



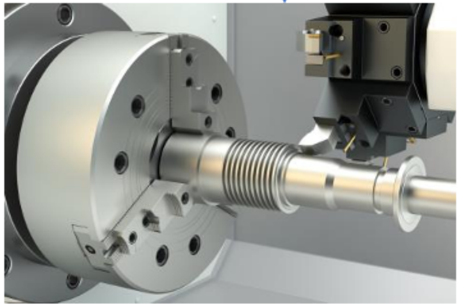
Many proofs

# I. Introduction

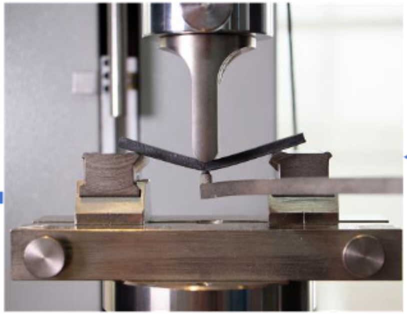
Physical requirement.

Idea formulation.

Optimization techniques



One prototype.



Mechanical test

# I. Introduction

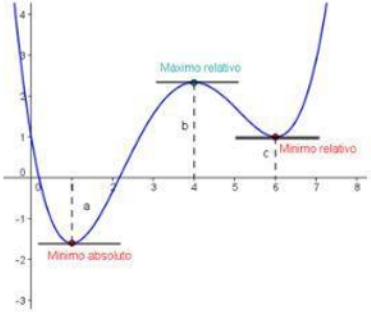
## Mathematical model

$$f(\mathbf{x}) = 0.6224x_1x_3x_4 + 1.7781x_2x_3^2 + 3.1661x_1^2x_4 + 19.84x_1^2x_3$$

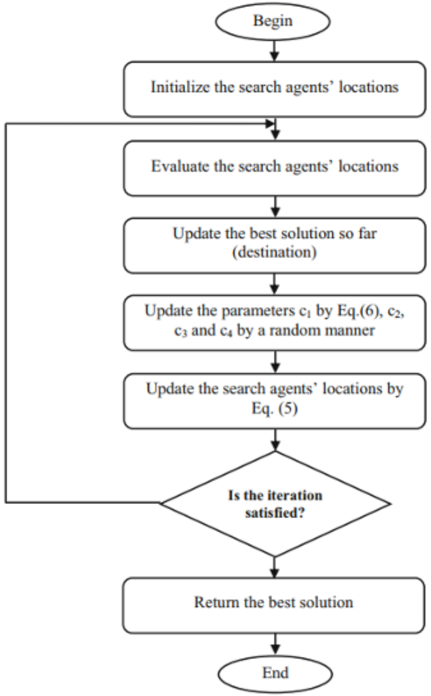
Subject to:

$$g_1(\mathbf{x}) = -x_1 + 0.0193x_3 \leq 0,$$
$$g_2(\mathbf{x}) = -x_3 + 0.00954x_3 \leq 0,$$
$$g_3(\mathbf{x}) = -\pi x_3^2x_4 - \frac{4}{3}\pi x_3^3 + 1,296,000 \leq 0,$$
$$g_4(\mathbf{x}) = x_4 - 240 \leq 0,$$
$$1 \times 0.0625 \leq x_1, x_2 \leq 99 \times 0.0625, \quad 10 \leq x_3, x_4 \leq 200.$$

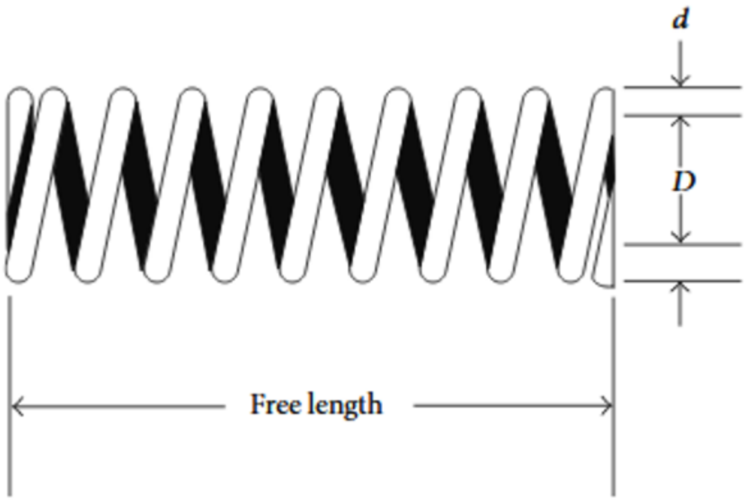
## Deliever an optimal solution




## Sequential programming



# II. Mathematical model




Case of study

| Parámetro | Valor | Unidad |
|---|---|---|
| G | 808543,6 | $kgf/cm^2$ |
| $\delta_w$ | 3,175 | cm |
| $N_{cmax}$ | 25 | - |
| α | 1,05 | - |
| β | 3 | - |
| $F_{max}$ | 453.6 | kgf |
| $L_{max}$ | 35,6 | cm |

# II. Mathematical model

## Objective function

Helical spring volume

$$V = \left(\frac{\pi}{2}\right)^2 (N_c + 2)Dd^2 \quad (1)$$

Subject to

Maximum stress

$$S = \frac{8C_f F_{max} D}{\pi d^3} \quad (2)$$

Free length

$$l_f = \delta_l + \alpha(N_c + 2)d \quad (3)$$

# II. Mathematical model

Constraints

| | | |
|---|---|---|
| Stress and maximum force relation | $g_1 = \pi d^3 S - 8C_f F_{max} D \geq 0$ | (4) |
| Free length | $g_2 = l_{max} - l_f \geq 0$ | (5) |
| Wire diameter | $g_3 = d - d_{min} \geq 0$ | (6) |
| Mean diameter | $g_4 = D_{max} - D - d \geq 0$ | (7) |
| Geometrical constraint | $g_5 = C - \beta \geq 0$ | (8) |
| Maximum allowed deflection. | $g_6 = \delta_{pmax} - \delta_p \geq 0$ | (9) |
| Free length and combined deflection | $g_7 = l_f - d_p \geq 0$ | (10) |
| Force constraint | $g_8 = F_{max} - F_p - k\delta_w \geq 0$ | (11) |

# III. Solution technique

Classic metaheuristic technique used to solve nonlinear mathematical problems.

It works by turning a constricted problem into a conditional one.

It's a populational algorithm which works with descending populations.

The best individuals are selected via tournament.

The new population and its advance is determined by mutation and recombination parameters.

```
Data: Parameters for the implementation of CGA,
      Parameters of the mathematical model.
for t = 1 : t_max do
    m = 0;
    if t == 1 then
        Generate the initial population;
        for i = 1 : a do
            Evaluate the fitness function;
        end
    else
        Generate the descending population;
        for i = 1 : a do
            Evaluate the fitness function;
        end
        Determine the new population;
        if (m > m_max || t == t_max) then
            Result: Impress results
            Break;
            ;
        end
    end
end
```

# III. Solution technique

Fitness function

$$FF = V + Pen$$

$$Pen = (p_1 + p_2 + p_3 + p_4 + p_5 + p_6 + p_7 + p_8)\theta$$

$$p_1 = \max\{0, g_1\}$$

$$p_2 = \max\{0, g_2\}$$

$$p_3 = \max\{0, g_3\}$$

$$p_4 = \max\{0, g_4\}$$

$$p_5 = \max\{0, g_5\}$$

$$p_6 = \max\{0, g_6\}$$

$$p_7 = \max\{0, g_7\}$$

$$p_8 = \max\{0, g_8\}$$

Codification

| Wire diameter | Mean diameter | Number of active coils |
|---|---|---|
| d | D | $N_C$ |

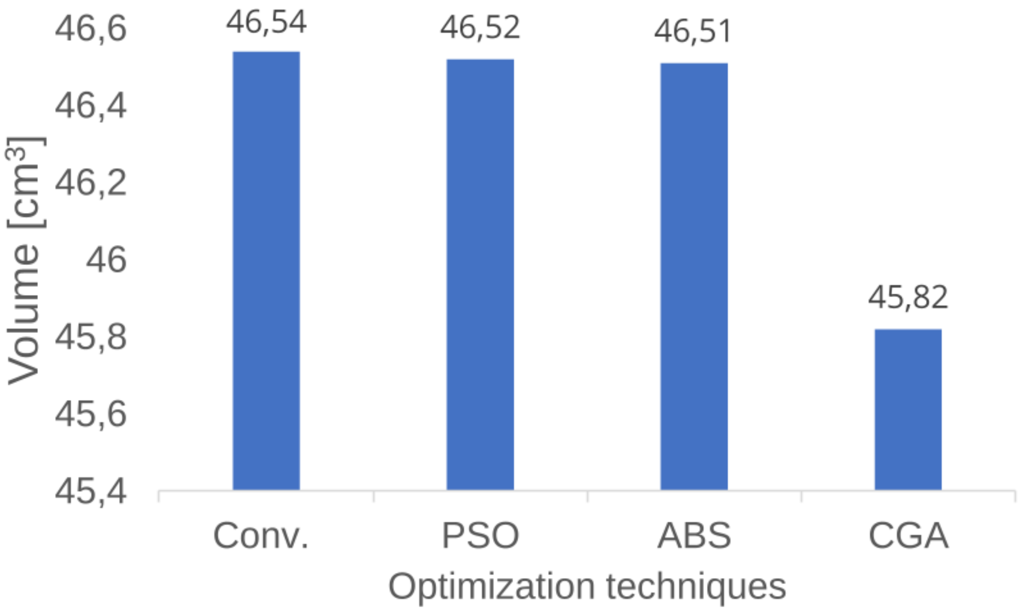
# IV. Results

Best solution found by the CGA being 1,5% less than the best reported technique.

Processing time 1 s.

Solution values.

| d | D | Nc |
|---|---|---|
| 0,674 | 2,405 | 15 |



# V. Conclusions

The solution found by CGA satisfy all the technical constraints.

Improve the quality of the solution at a low computational cost.

Prove to be an efficient tool to solve nonlinear, non-convex problems as the described in the mathematical model.

CGA can be used to solve optimization problems related to the design of machine elements.

# VII. Questions

# VII. References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