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Optimal Solution for an Engineering Applications Using Modified Artificial Immune System

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Abstract. An Engineering optimization leads a essential role in several engineering application areas like process design, product design, re-engineering and new product development, etc. In engineering, an awfully best answer is achieved by comparison to some completely different solutions by utilization previous downside information. An optimization algorithms provide systematic associate degreed economical ways that within which of constructing and comparison new design solutions so on understand at best vogue, thus on best solution efficiency and acquire the foremost wonderful design impact. In this paper, a new evolutionary based Modified Artificial Immune System (MAIS) algorithm used to optimize an engineering application of gear drive design. The results are compared with existing design.

1. Introduction

Most engineering optimization problems normally have continuous and discrete design variables with usually conflicting with each other. These problems with several objectives, are called "multi objective" optimization problems, and were initially studied as nonlinear objective functions. Constraints are extremely vital in engineering design problems with nonlinear constraints, usually obligatory on the statement of the issues and generally are terribly exhausting to satisfy, that makes the search tough and inefficient.

A computational paradigm system called Artificial Immune System (AIS) which is inspired by the biological immune system. It is based on the principal of the natural system. This system is based on the general Immune system as in our body. This system finds application in the future computerized industries, Robotics, Aerospace, automotive, etc., because of its immune system which develops its own antibodies for the virus or foreign bodies which will harm the system and also because of its identification system which identifies the previous attack or problem and produce solution for that .These are the main reason for the attraction towards the system AIS.

Yap, David et al [1] proposed the clonal selection algorithm is modified using the best solutions for each exposure (iteration) namely Single Best Remainder (SBR) and the proposed algorithm is able to improve the conventional CSA in terms of accuracy and stability for single and multi objective functions. Deb at al [2] discussed immune system for his first-generation algorithms use simplistic models of immunology as the initial inspiration, for example negative and clonal selection.

Coello and Cortes [3] developed multiobjective immune system algorithm (MISA) for its employment of an AIS in a multiobjective evolutionary algorithm context. Woldemariam [4], his research exploits the fact embedded in the immune system to communicate between innate immune

response and adaptive immune response levels. Luh et al. [5] Proposed a Multi-objective Immune Algorithm (MOIA), MO-AIS research grew into maturity. Following that tens of algorithms were proposed.

Garrett [6] developed Adaptive Clonal Selection (ACS) by improving a number of processes and parameter initialization. Research based on aiNet extended aiNet to opt-aiNet. Wu, J.Y. [7] Proposed algorithm which combines the metaphor of clonal selection and idiotypic network theories to design an AIS method.

The somatic hypermuation and receptor editing operators explore a search space of solutions to an optimization problem. Juan Carlos Herrera–Lozada et al [8] proposed a new cloning system and for the maturation stage of the clones, two simple and fast mutation operators are used in a nominal convergence that works together with a re-initialization process to preserve the diversity. In this paper, a new immune clonal system based Modified Artificial Immune System (MAIS) algorithm used to optimize the helical gear drive design..

2. Artificial Immune System Algorithm

Artificial Immune Systems square measure new intelligent drawback determination techniques that square measure getting used in varied engineering optimization issues. AIS are outlined as procedure systems impressed by theoretical medicine, ascertained immune functions, principles and mechanisms so as to resolve issues. Because the biological processing algorithms, artificial system has been with success applied to a range of optimization issues.

AIS square measure a procedure intelligence paradigm impressed by the biological system that has found application in pattern recognition and machine learning. Alternative ways of AIS for optimization because the immune network theory and therefore the organism choice principle are projected and enforced by totally different researchers. The steps of the Modified Artificial Immune system as followed:

Generate randomly a population of "N" size with design variables. In the initial generation, these variables are copied directly to the working population and nominal convergence is controlled by the number of generations.

1. Finding the Objective Function for those variables and continued for sorting and ranking.
2. Use selection based on ranking. The variables with the highest affinity will be the best individual.
3. Perform the cloning of the antibodies using, $N_C = \sum (n - (i - 1))$ Where NC is the number of clones to be generated for each variable, n is the total number of variable in the population and i is the current variables starting from the variables with the highest affinity [8].
4. All the clones in the set of clones which are the copies of variables with good affinity degrees, undergo a mutation process [8]. This is a two phased mutation process

$$x' = x + \frac{(\alpha \times \text{ range } \times \text{ generation})}{N_c}$$

and

$$x' = x + \frac{(\alpha \times \text{ range})}{\text{generation} \times N_c}$$

5. After the first mutation operator, In the case of having a better solution in mutated string, then the clone is replaced with the new one, else the second operator is used.
6. In the second mutation method, if there is no improvement in the mutated string, then the original solution remains with no change.
7. A model of receptor editing mechanism of the immune system was used, i.e., a proportion of the worst solution eliminated and new ones are generated in placed after predefined iterations.
8. Again find the objective function for the clones and sort it, rank it, mutate it then extract first best 10 solutions from the list for the further design process and visualization.

3. Engineering Design Application

In this paper, an engineering design problem has been adopted from Jayakumar [9]. The design problem states that, to design a pair of helical gears to transmit 12.5 kW at 1200 rpm. The transmission ratio is 3.5 and material adapted as Alloy steel material 40Ni 2Cr1Mo28. The helix angle is 15º and pressure angle is 20º. The material properties of gear drive are tabulated [11] in Table 1.

Table 1. Material Properties of Gear drive.

Material	Density(ρ) kg/mm3	Bending Stress(σb) kg/mm2	Compressive Stress (σc) kg/mm2	Young's Modulus (E) N/mm2
Alloy Steel	8.839x10-6	173.133	852.6	2.15x105

3.1. Optimal Helical Gear Drive Design

The design variable such as module, gear thickness and number of teeth are determined in order to optimize the helical gear drive design and number of objective functions include: Maximization of Power transmitted (f1),Minimization of Weight (f2), Maximization of Efficiency (f3) and Minimization of Centre distance (f4). The above gear drive objectives should satisfies with the design constraints of allowable bending stress, allowable compressive stress, minimum module and minimum centre distance.

The complete optimized problem of helical gear drive in terms of design variables P, mn, b and Z1 for the above problem with Alloy steel material, after simplification the helical design problem is in terms of non linear objectives and non linear constraints as follows:

Maximize $\quad f_1 = P$ $\hspace{4cm}$ (1)

Minimize $\quad f_2 = 98.58 \times 10^{-6} \times b \times (m_n Z_1)^2$ $\hspace{2cm}$ (2)

Maximize $\quad f_3 = 100 - P_L$ $\hspace{3.5cm}$ (3)

Where, $P_L = 3.97 \times \dfrac{(H_s^2 + H_t^2)}{(H_s + H_t)}$ $\hspace{3cm}$ (4)

$$H_s = 4.5 \times \left\{ \left[\left(1 + \frac{0..552}{Z_1}\right)^2 - 0.883 \right]^{0.5} - 0.342 \right\} \quad (5)$$

$$H_t = 1.286 \times \left\{ \left[\left(1 + \frac{1.931}{Z_1}\right)^2 - 0.883 \right]^{0.5} - 0.342 \right\} \quad (6)$$

Minimize $f_4 = 2.33 \, m_n Z_1$ $\hspace{4cm}$ (7)

Subject to,

$\quad m_n Z_1 \ b^{0.5} \ P^{-0.5} \ \geq \ 65.741$ $\hspace{3cm}$ (8)

$$m_n^2 \, (3.5Z_1 + 20) \, b \, P^{-1} \geq 250.51 \qquad\qquad (9)$$

$$m_n \, Z_1 \, P^{-0.333} \geq 18.35 \qquad\qquad (10)$$

$$m_n^3 \, (3.5Z_1 + 20)^{0.333} \, P^{-0.333} \geq 2.94 \qquad\qquad (11)$$

The efficiency equation (3) has been adopted from Dudley [10] and all other equations followed from Design Data book [11].

Since all these objective functions are on different scales, these factors are to be normalized to the same scale. The normalized objective function is obtained as follows:

COF=

$$\left[\left(\frac{power}{max\,.power} \, xNW_1 \right) + \left(\frac{min\,.weight}{weight} \, xNW_2 \right) + \left(\frac{efficiency}{max\,.efficiency} \, xNW_3 \right) + \left(\frac{min\,.cent.dist}{cent.dist} \, xNW_4 \right) \right]$$

5. Results and Discussion

The above algorithm was developed using Microsoft Visual C#, with design parameters (P, mn, b and Z1) boundary values as inputs. After iteration of AIS for the specified helical gear reducer, the optimized results were tabulated in table 2 and compared with existing design [9]. The AIS result shows, significantly enhanced values with respect to weight reduction and center distance for the helical gear drive.

Table 2. Comparison of gear drive optimized results with MAIS.

Parameters / Material	Existing System	MAIS
Power (P) kW	12.5	12.52
Normal Module (mn) mm	3.00	2.76
Gear Thickness (b) mm	42.00	35.62
No. of teeth on pinion (Z1)	20	18
Centre Distance (a) mm	139.76	115.72
Gear Weight (kg)	14.9	8.66
Efficiency (%)	98.67	98.54

The above results shows, a slight increment in power and 41.88% of weight reduction for the existing alloy steel material with respect to MAIS result, and also significant reduction of 17.2% center distance in compared with existing system. From the results, MAIS produces a vital enhancement in its optimal design values to its objectives.

6. Conclusion

The engineering design problem results shows that, by using the AIS algorithm we can get the modified better solution for the practical problem and also for the theoretical problem.

In future, AIS will play the major role in the industries like automotive, aerospace, robotics, manufacturing etc., and it's also easy to understand and explain to the followers as it contains the

natural human immune system as it base. And also by using AIS we can also solve the multi objective problems which contains different nonlinear, non-differentiable and multi variables objective functions. By using AIS we can assure that the better solution are extracted using better values for the betterment of the design.

Notations

H_s :Specific sliding velocity at start of approach action
Ht   : Specific sliding velocity at end of recess action.
 P   : Power transmitted in kW
Z_1, Z_2: Number of teeth in pinion, gear
m_n : Normal Module in mm
i   : Gear (or) transmission ratio
b   : Thickness of gear and pinion in mm
a   : Centre distance between shafts in mm
ρ   : Density of the material in kg/mm^3
E   : Young's modulus in N/mm^2
σ_b : Induced bending stress in N/mm^2
$[\sigma_b]$: Allowable bending stress in N/mm^2
σ_c :Induced compressive stress in N/mm^2
$[\sigma_c]$: Allowable compressive stress in N/mm^2
η   : Percentage Efficiency
P_L: Percentage of power loss

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