

Beam Cost Optimization with Differential Approach and Simulate on ANSYS Tool

Barnabus Gurung¹, Manjit Kaur²

^{1,2} Department of Civil Engineering, Indo Global College of Engineering, Mohali, (India)

ABSTRACT

The purpose of this thesis is to perform a structural optimization of a flat plate having a sandwich configuration. This task is developed computationally through the interface between an optimization algorithm and the finite element method, with the goal of maximizing the stiffness of the structure where optimization can be done easily. Optimization techniques are mostly applied using single software. In this paper an advanced optimization technique, Differential Algorithm is implemented by coupling MATLAB and ANSYS. Thus the finite element analysis of ANSYS can be effectively utilized in the search algorithm in MATLAB. In this paper optimized length and width of beam is found by differential algorithm. This optimized value is used to model a beam in ANSYS. The modeled optimized beam is simulated and it showed better stability against heat, stretch and load compared to the non optimized beam. The volume of the beam is optimized under constraint of stress limited to the yield stress. Thus the optimized tool so developed becomes a powerful optimization technique. In addition the user can easily modify the parameter for optimization and its geometry.

Keywords - ANSYS , Beams, Mat Lab, Simulation.

I INTRODUCTION

Optimization is the process of finding an alternative with the most cost effective or highest achievable performance under the given constraints, by maximizing desired factors and minimizing undesired ones. In comparison, maximization means trying to attain the highest or maximum result or outcome without regard to cost or expense. Beam is a structural member which is ordinarily set horizontally. It gives resistance to bending when burdens are connected on it. Different types of materials, for example, wood, steel, aluminum, etc. are utilized for constructing beam. Most ordinarily utilized material for beam is RCC (Reinforced Cement Concrete). RCC beam can be different types relying upon different criteria. For example, contingent upon shape, beam can be rectangular, T-beam, etc. Contingent upon reinforcement placement, beam can be two fold strengthened beam, single fortified beam, etc. Structure design includes function design and optimum design. The function design emphasize that structure will not fail, but some aspect of structure can also improve. Optimization helps to achieve a feasible design, for a specified design objective. There are many optimization techniques based on mathematical programming to obtain optimum solutions. In the advanced optimization technique differential algorithm is the most popular one. Various papers and journals were studied and analyzed and a new cost optimization technique was created.

Vidhatri Gujela and Om Prakash Gujela et al. [2016]: performed the simulation of cantilever beam using ANSYS for Nano manipulator. Steel, Aluminum alloy and Polyethylene was used for design of beam type structure. The structural analysis was conducted by applying the force of 0.001μN to 0.8 N. The length of beam has been varied from 80μm, 120μm, 160μm, the width has varied 10μm, 20μm, 30μm and the thickness has been 0.6μm, 1.2μm, 1.8μm. The structural analysis has been performed by varying the parameters like beam length, width, thickness of the beam and the applied force. Simulation results show that the polyethylene is the suitable material for cantilever type beam for use in a Nano manipulator. **K.R. Indu and Irin M.G et al. [2015]:** performed advanced optimization technique; here Genetic Algorithm (GA) is implemented by coupling MATLAB and ANSYS. Here the finite element analysis of ANSYS can be effectively utilized in the search algorithm in MATLAB. A tapered hollow cantilever beam is optimized using the above methodology. An optimum design complying with the design constraints is obtained. The volume of the cantilever beam is optimized under constraint of stress limited to the yield stress. From the optimized result it was seen that the volume of the structure got reduced considerably. The results obtained showed better optimization of the beam.

S Darshan, Akshay Varik, Anirudh N Katti, Amit Kumar Singh and Rahul R Kamath et al. [2013]: researched in size and topological optimization of cantilever beam. The governing idea was to reduce the mass of the beam for a given strength. The cross section under consideration is a rectangular one. A Graphical Approach was adopted to plot SOM equations on Mat lab to obtain a common acceptable domain. A traditional method, Johnson's method was considered to account for fatigue strength of the material and obtain optimum dimensions. Finally COMSOL software was used to topologically optimize the beam. This paper attempted to provide a bird-eye view of the structural optimization, with a special emphasis on its relation to optimization of cantilever beam. **Ali R Yildiz et al. [2013]:** Compared of evolutionary-based optimization techniques for structural design. Furthermore, a hybrid optimization technique based on differential evolution algorithm is introduced for structural design optimization problems. In order to evaluate the proposed optimization approach a welded beam design problem taken from the literature is solved. The proposed approach is applied to a welded beam design problem and the optimal design of a vehicle component to illustrate how the present approach can be applied for solving structural design optimization problems. A comparative study of six population-based optimization algorithms for optimal design of the structures is presented. The volume reduction of the vehicle component is 28.4% using the proposed hybrid approach. The results show that the proposed approach gives better solutions compared to genetic algorithm, particle swarm, immune algorithm, artificial bee colony algorithm and differential evolution algorithm that are representative of the state-of-the-art in the evolutionary optimization literature.

W. Chen¹, Y.-Z. Zhang¹, J.-H. Ma¹, B.-X. Wang², Y. Chen¹ and C. Wang¹ et al [2011]: developed a new optimization program to search out the optimum processing parameters for beam blank continuous casting. The parameters optimizing method is set up combined the multi-objective genetic algorithms (based on MATLAB) with finite element method (based on ANSYS). The finite element method is used to calculate the thermo-



mechanical process for beam blank continuous casting. The multi-objective genetic algorithm is used to search out the optimum processing parameters for beam blank continuous casting. Those optimum parameters can meet all specified requirements but with a minimum expense of the operational and the design constraints and can make it possible to run the caster at its maximum productivity, minimum cost and to cast defect free products. Now, online verifying of this optimization project has been put in practice, which can prove that it is very helpful to control the real production. Compared with the zero order method, the result of this optimizing method is better. This developed optimizing method, taking full advantage of the feature of FEM that computes precisely and the feature of MOGA that search the optimal solution globally and rapidly, provides a method for solving the complex and large engineering problem, especially to the multi-objective optimizing problems

II OPTIMIZATION

Optimization is obtaining the best result under given circumstances. In design, construction and maintenance of any engineering system, engineers have to take many technological and managerial decisions at several stages. The ultimate goal of all such decisions is either to minimize the effort required or to maximize the desired benefit. A number of optimization methods have been developed for solving different types of optimization. An optimization problem consist of maximizing or minimizing a real function by systematically choosing input values from within an allowed set and computing the value of the function. The generalization of optimization theory and techniques to other formulations comprises a large area of applied mathematics. More generally, optimization includes finding “best available” values of some objective function given a defined domain (or input), including a variety of different types of objective functions and different types of domains.

The various types of advanced optimization techniques are; Differential algorithms, intelligent optimization, Swarm and evolutionary optimization techniques, Single and multi-objective optimization, Structural optimization, Size shape and topology optimization, Simulated annealing, Genetic algorithms, Pollination based algorithms, Ant colony optimization, etc. Civil engineers are involved with the creation, monitoring and management of infrastructural resources, as well as the efficient, economic utilization and management of renewable natural resources. Nowadays a rapid growth of computer performance enables and encourages new development in civil engineering as well as related areas. For instance, the construction industry investigates new design with minimum cost, minimum CO₂ emissions, or embodied energy, among other objectives.

2.1. Differential Algorithm

In computer science, evolutionary computation is a family of algorithms for global optimization inspired by biological evolution, and the subfield of artificial intelligence and soft computing studying these algorithms. An algorithm is a self-contained sequence of actions to be performed. Algorithms can perform calculation, data processing and automated reasoning tasks. It is an effective method that can be expressed with a finite amount of space and time and in well-defined formal language for calculating a function. Global optimization is a branch of applied mathematics and numerical analysis that deals with the global optimization of a function or a set of functions according to some criteria. Differential Evolution (DE) in evolutionary computation is a method



that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality.

A basic DE algorithm works by having a population of candidate solutions (called agents). These agents are moved around in the search-space by using simple mathematical formula to combine the positions of existing agents from the population. If the new position of an agent is an improvement it is accepted and forms a part of the population, otherwise the new position is simply discarded. The process is repeated and by doing so it is hoped that a satisfactory solution will be discovered. Differential evolution algorithm is invented by Storn and Prince in 1995. Differential Evolution has been shown to be a simple yet efficient optimization approach in solving a variety of benchmark problems as well as many real world applications. Differential evolution together with evolution strategies (ES's) and evolutionary programming (EP) can be categorized into a class of population –based, Derivative free methods known as Evolutionary algorithm. All this approaches mimic Darwinian evolution and evolve a population of individuals from one generation to another by analogous evolutionary operations such as mutation, crossover and selection.

III TOOLS

The tools that are used in this research papers are Matlab and ANSYS. MATLAB (MATrix LABoratory) is a high-performance interacting data-intensive software environment for high-efficiency engineering and scientific numerical calculations. MATLAB enable the users to solve a wide spectrum of analytical and numerical problems using matrix-based methods, attain excellent interfacing and interactive capabilities, compile with high-level programming languages, ensure robustness in data-intensive analysis and heterogeneous simulations, provide easy access to straight forward implementation of state-of-the-art numerical algorithms, guarantee powerful graphical features. Here, we are using MATLAB R2014a in which optimization is done. It is a numerical computing environment and fourth generation programming language; it allows matrix manipulations, plotting of function and data, implementation of algorithms. The MATLAB application is built around the MATLAB scripting language. Common usage of the MATLAB application involves using the Command Window as an interactive mathematical shell or executing text files containing MATLAB code.

ANSYS is engineering analysis software which includes Finite element analysis, structural analysis, heat transfer and computational fluid dynamics. ANSYS is a global leader in engineering simulation. It is computer – aided engineering software which used to analyses structure, finite elements, dynamic elements etc. . For Civil Engineering Projects an advanced, comprehensive and reputable finite element analyses and design software is presented as a system. In this system there is a combination of features of state-of-the-art of ANSYS (ISO-9001) with civil engineering- specific structural analysis capabilities of civil FEM for structural analyses.

IV METHODOLOGY

The beam cost optimization with a differential approach using MATLAB software and simulation on ANSYS is done to get a cost effective beam. The differential algorithm is used to optimize the length and width of the beam in MATLAB. Further the beam is simulated on ANSYS tool and comparison of optimized and non-

optimized beam with respect to heat, stretch and load is done. This process can be further shown in the flow chart given below:

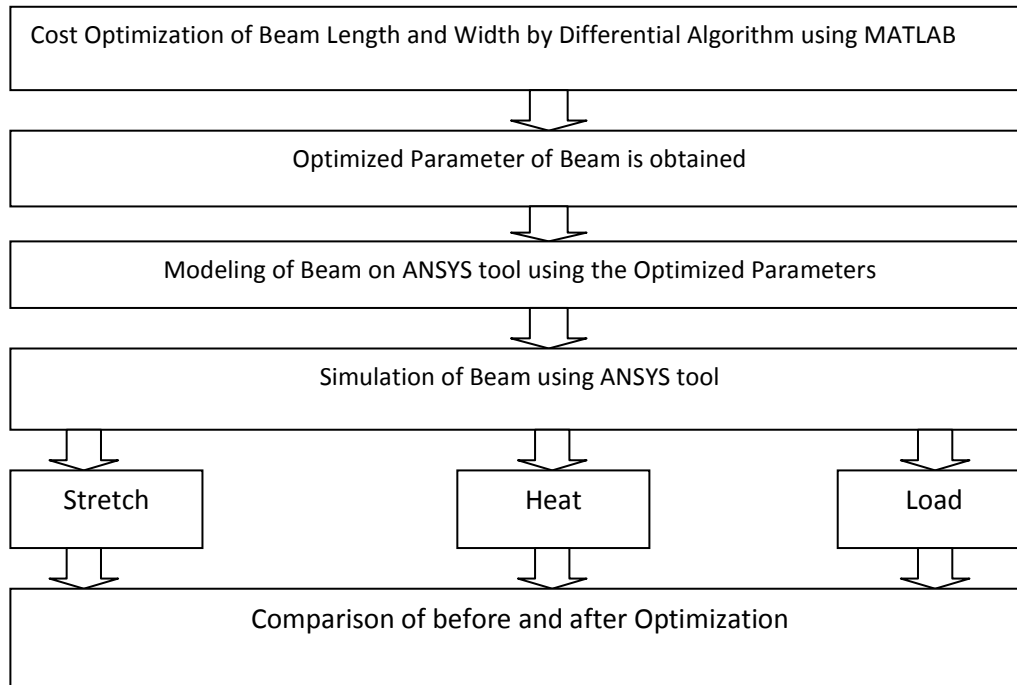


Figure 4.1: Flow chart (Methodology)

4.1. Differential Algorithm for Cost Optimization of Length and Width of Beam

The step by step process which is followed to obtain the optimum value is given further. The differential algorithm method followed for cost optimization of beam length is given in the flow chart above:

Begin

Step 1: Initialization: initialize n_p real vector at random.

Step 2: Select the random vector and weighted factor f and crossover constant C .

Step 3: The fitness function for individual p is evaluated.

Step 4: While criteria halt is not satisfied do

For $n-1$ to n_p do

Select random vector $R_1 \neq R_2 \neq R_3 \neq n$

$rnd_m = [n_p * rnd]$

for $rnd \leq C$ or $m == rnd_m$ then

$v_1(m) = x_{R_1}(m) + f \times [x_{R_2}(m) - x_{R_3}(m)]$

else

$v_1(m) = x_1(m)$

end if

end for

for $n=1$ to n_p do
Evaluate objective function u_n
If u_n is better than p_n then
 $P_n = u_n$
End if
End for
Converged best solution, $T=T+1$
Step 5: end while the length L_R is optimized
end

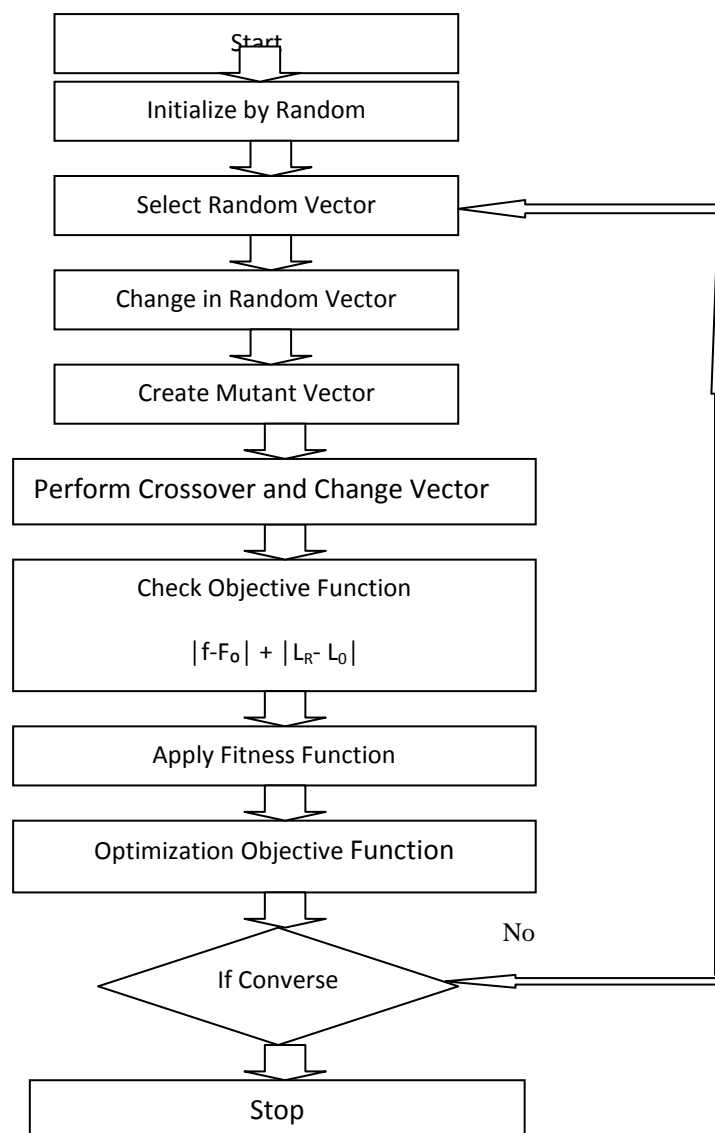


Fig 4.2: Differential Algorithm for Beam Length Cost Optimization.

Similarly the differential algorithm method followed for the cost optimization of beam width is given below in the flow chart:

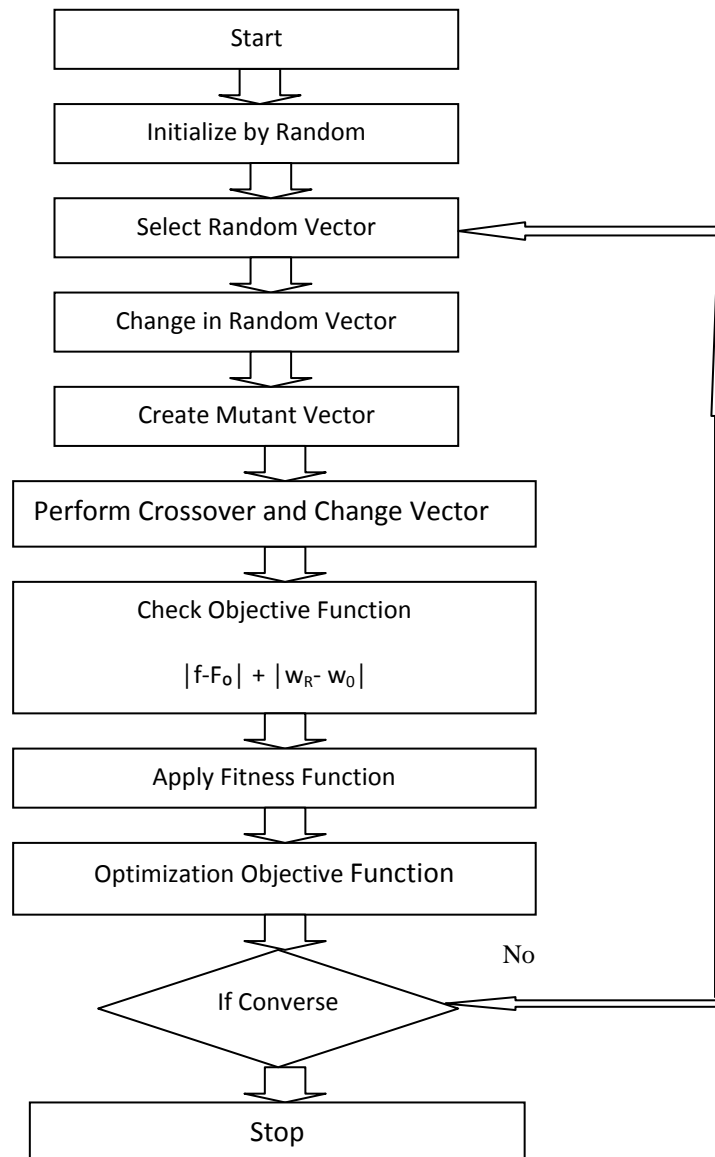


Fig 4.3: Differential Algorithm for Beam Width Cost Optimization.

Begin

Step 1: *Initialization:* initialize n_p real vector at random.

Step 2: Select the random vector and weighted factor f and crossover constant C .

Step 3: The fitness function for individual p is evaluated.

Step4: *While* criteria halt is not satisfied *do*

For $n-1$ to n_p *do*

Select random vector $R_1 \neq R_2 \neq R_3 \neq n$



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rndm = [np * rnd]
for rnd ≤ C or m = rndm then
    v1(m) = xR1(m) + f × [xR2(m) - xR3(m)]
else
    v1(m) = x1(m)
end if
end for
for n = 1 to np do
    Evaluate objective function un
    If un is better than pn then
        Pn = un
    End if
End for
Converged best solution
T = T + 1
Step 5: end while the width WR is optimized
End
    
```

4.2. Modelling on ANSYS

ANSYS, Inc. is an engineering modelling and simulation software that offers engineering simulation solution sets in engineering simulation that a design process requires. Here, we are using ANSYS WORKBENCH 14.0 in which modelling of beam is done in geometry component system, material is selected from engineering data library and simulation & analysis is performed. The optimized value obtained from the differential algorithm is further taken into account and are used to model a beam. The various other properties such as elastic modulus, major poisson ratio, coefficient of thermal expansion, thermal conductivity and electrical resistivity are adopted. The materials model defined for simulation is given below:

- EX = 1.69×10^{11} = Elastic Modulus, element in X direction.
- PRXY = 0.22 = Major Poisons Ratio x-y plane.
- ALPX = 2.9×10^{-6} = Coefficient of thermal expansion, element x direction.
- KXX = 1.5×10^8 = Thermal Conductivity , element x direction
- RSVX = 2.3×10^{-10} = Electrical resistivity, element x direction

The modelling of the beam with cantilever support on ANSYS tool is given below in the figure:

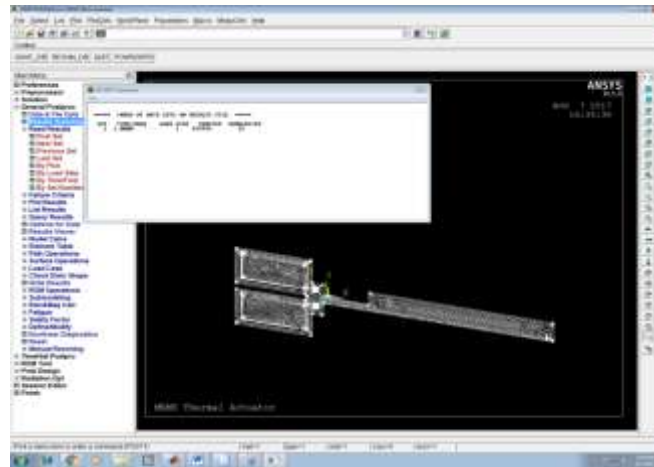


Fig 4.4: Cantilever Beam on ANSYS tool.

V RESULTS AND DISCUSSION

The cost optimization of beam with respect to its length and width using differential algorithm was carried out in MATLAB software. The results are found out and are tabulated in the table and further represented in the graph. The optimized value is modelled and simulated on ANSYS tool. This simulation is represented by a graph where the comparison between optimized and non-optimized beam is done.

5.1. Cost Optimization on MATLAB.

The cost optimized length and breadth of the beam is obtained by differential approach on MATLAB software. There is a process of repetitive iteration to get the best cost. This iteration is further tabulated and its graph is also plotted which is shown below in the figure.

Table no 1: Number of iteration that takes place for optimization of length.

Iteration	Best Cost	Length (L1)	Length (L2)
05	4.285403	2.01298	2.70112
10	1.866890	1.88462	5.24844
15	1.803710	4.43049	2.7653
20	1.803710	4.43049	2.7653
25	1.803710	4.43049	2.7653
30	1.437473	6.5367	1.02583
35	1.437473	6.5367	1.02583
40	0.635852	6.94046	1.42369
45	0.635852	6.94046	1.42369
50	0.635852	6.94046	1.42369

55	0.635852	6.94046	1.42369
60	0.635852	6.94046	1.42369
65	0.635852	6.94046	1.42369
70	0.23765	6.96818	1.79417
75	0.23765	6.96818	1.79417
80	0.23765	6.96818	1.79417
85	0.23765	6.96818	1.79417
90	0.23765	6.96818	1.79417
95	0.23765	6.96818	1.79417
100	0.23765	6.96818	1.79417
105	0.23765	6.96818	1.79417
110	0.23765	6.96818	1.79417
115	0.23765	6.96818	1.79417
120	0.23765	6.96818	1.79417
125	0.23765	6.96818	1.79417
130	0.23765	6.96818	1.79417
135	0.23765	6.96818	1.79417
140	0.23765	6.96818	1.79417
145	0.23765	6.96818	1.79417

The graph between iteration and best cost and between length1 and length2 is shown below in the figure.

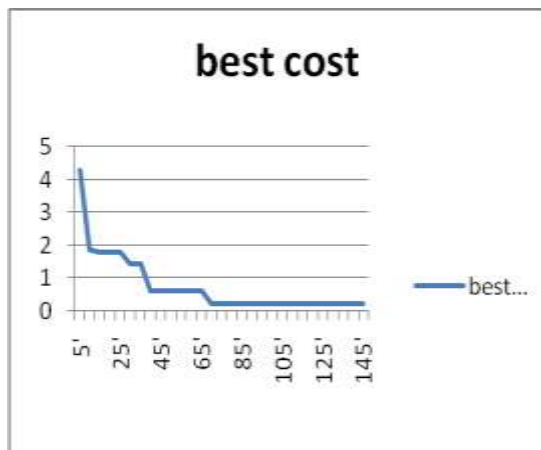


Fig 5.1: Graph between iteration and best cost.

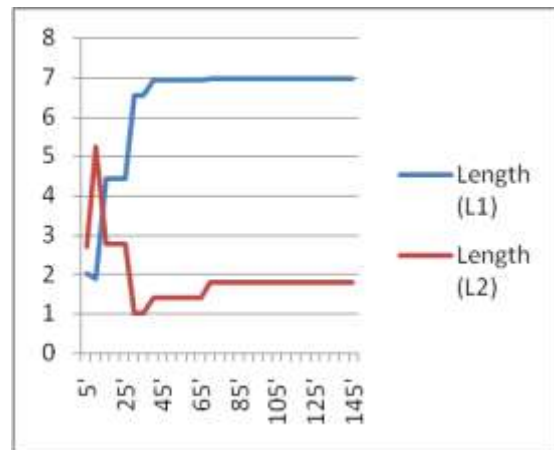


Fig 5.2: Graph between length1 and length2

Similarly the iteration that takes place the cost optimization of beam width and its graphical representation is shown below in the figure.

Table no 2: Number of iteration that takes place for optimization of width.

Iteration	Best Cost	Width (1)	Width (2)
05	2.964297	3.3976	2.6381
10	1.434487	3.04487	4.50669
15	0.434487	6.85102	1.71449
20	0.394370	6.68108	1.92455
25	0.394370	6.68108	1.92455
30	0.352091	6.69786	1.95005
35	0.130904	6.84668	2.02242
40	0.130904	6.84665	2.02242
45	0.130904	6.84668	2.02242
50	0.130904	6.84668	2.02242
55	0.130904	6.84668	2.02242
60	0.130904	6.84668	2.02242
65	0.098576	6.84689	2.03252
70	0.052922	6.97139	1.97568
75	0.052922	6.97139	1.97568
80	0.052922	6.97139	1.97568
85	0.042675	6.98388	1.97345
90	0.014266	6.98018	2.00586
95	0.006364	6.99962	1.99399
100	0.006364	6.99962	1.99399
105	0.006364	6.99962	1.99399
110	0.006364	6.99962	1.99399
115	0.006364	6.99962	1.9981
120	0.006364	6.99579	1.99939
125	0.006364	6.99579	1.99939

130	0.006364	6.99579	1.99939
135	0.004817	6.99579	1.99939
140	0.004817	6.99579	1.99939
145	0.00049	6.99954	1.99996

The graph between the best cost and iteration and width1 and width2 is given below in the figure.

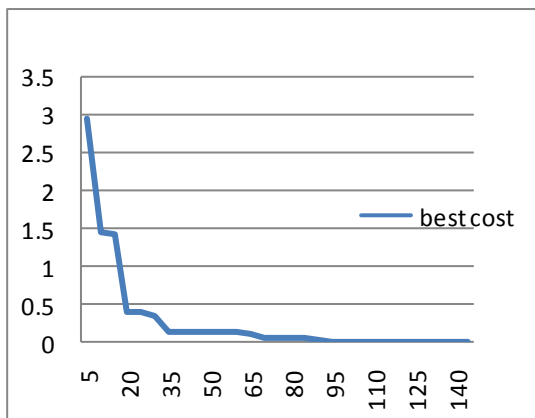


Fig 5.3: Graph between iteration and best cost.

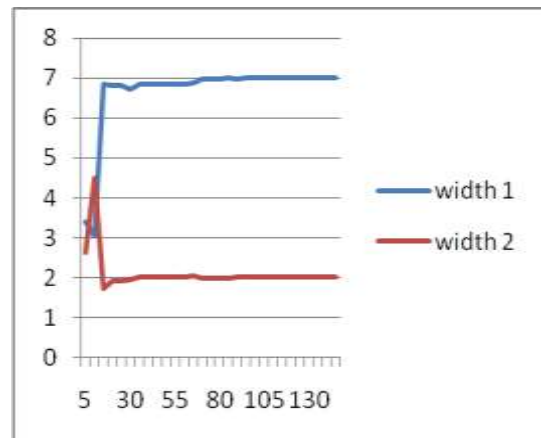


Fig 5.4: Graph between width1 and width2.

Table 3: Effects on the bearing capacity of a beam before or after optimization.

Parameters	Heat (joule)	Stress (N/M ²)	Load (KN)
With optimization	67	87	75
Without optimization	48	59	53

It is further represented in the graph which is shown below

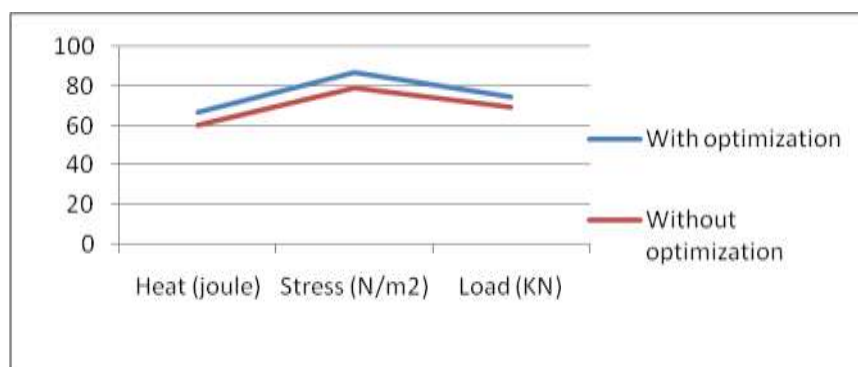


Fig 5.5: Comparison between before and after Optimization.

5.2. Simulation on ANSYS.

The beam of cantilever support is modeled on ANSYS tool by providing the optimized parameters and simulation is done. The simulation of beam with respect to stretch, heat and vibration is done. The comparison between the optimized and non optimized beam is done and the result shows that the optimized beam is stable to the environment and hence the cost optimization done by differential algorithm is effective. The figure below shows the simulated beam.

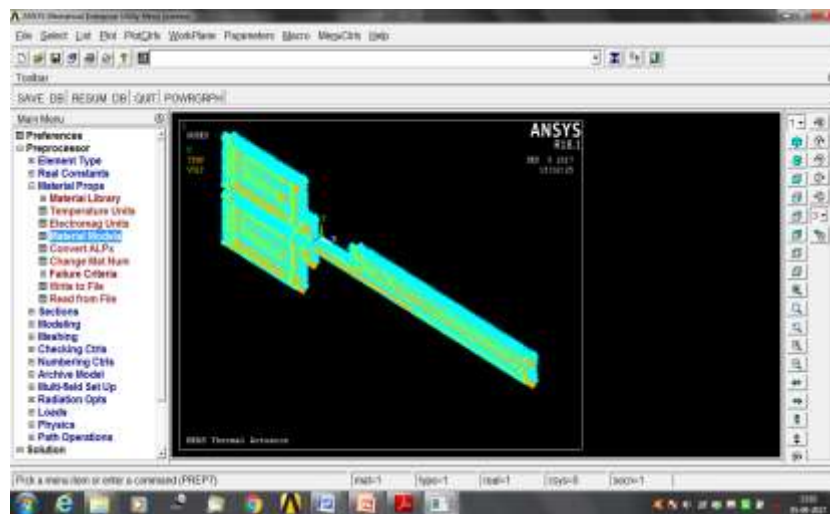


Fig 5.6: Simulated Beam

5.4. Simulation screenshots:

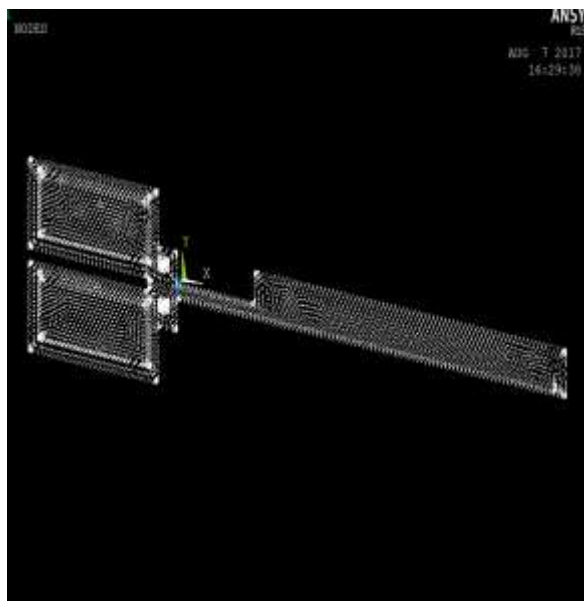


Fig 5.7: Screenshot 1

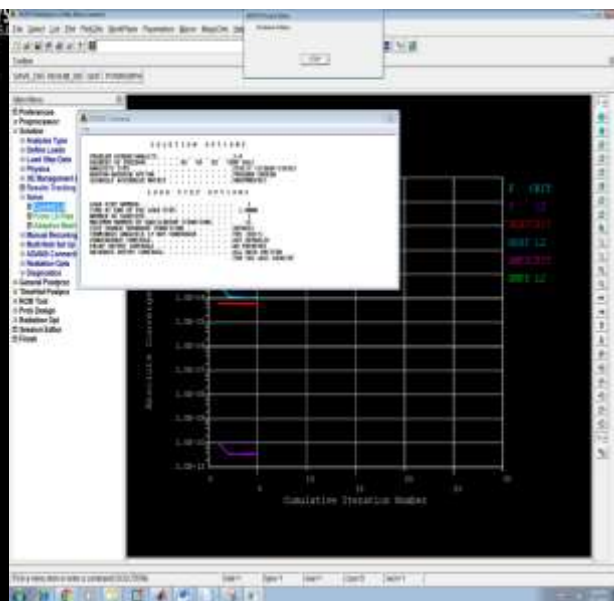


Fig 5.8: Screenshot 2

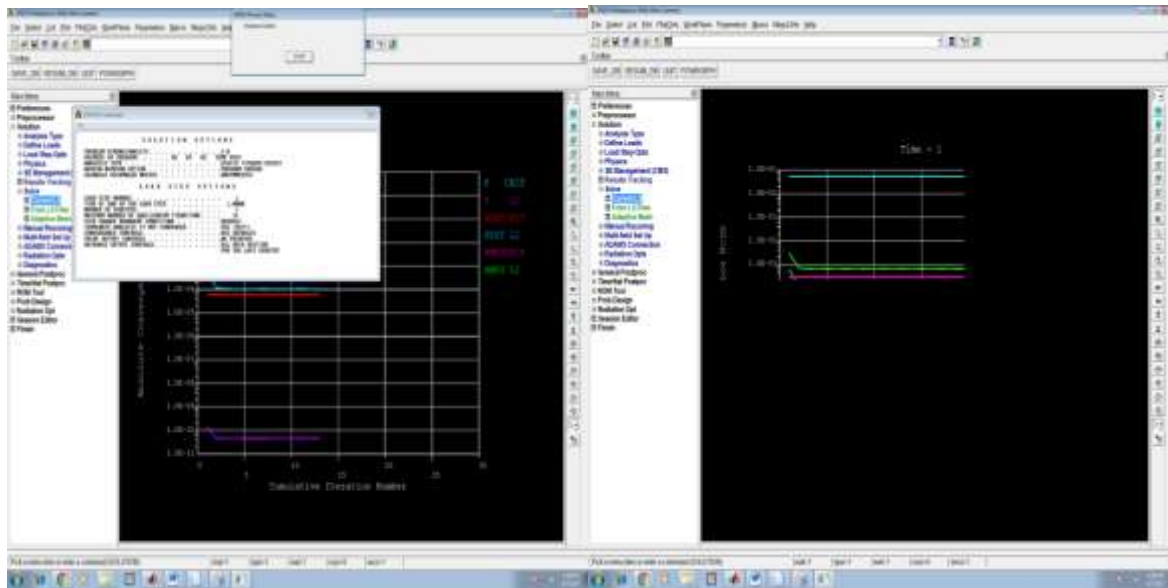


Fig 5.9: Screenshot 3.

Fig 5.10: Screenshot 4.

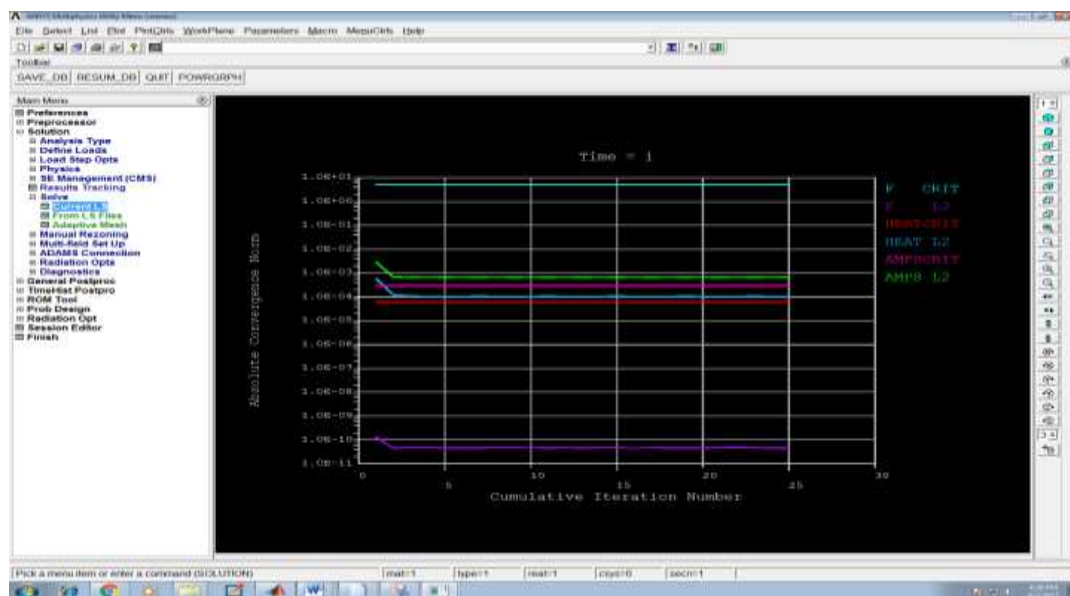


Fig 5.11: Screenshot 5

VI. CONCLUSION AND FUTURE SCOPE

This thesis introduces the subject of cost optimization by differential algorithm , treats fundamental optimization theory, explains how the software application works, and presents a case study that was carried out to evaluate the application. The result of the case study suggests a potential for significant cost savings with improvement of heat, stretch and load. Yet, the speeding up of the design process is perhaps the major benefit that should incline designers to favor optimization. These findings mean that current optimization algorithms are robust

enough to decrease the cost of beam compared to a conventional design. However, the software application needs several improvements before it can be used in a real situation, which is a topic of future research.

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