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DYNAMIC MODELLING OF WORKPIECE FIXTURE SYSTM USING ELASTIC CONTACT MODEL

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ABSTRACT

The Generalised Rigid Body Model (RBM) predicts contact forces analytically. The WFS was simulated using the Finite Element Analysis-based Elastic Rigid Body Model (FEA-ERBM) to estimate elastic deformation and contact forces for a fixture arrangement configuration. The Parametric Finite Element Analysis-based Elastic Contact Model (PFEA-ECM) predicts workpiece elastic deformation and allows easy design parameter changes without changing the foundation model. FLD optimisation approaches include genetic algorithms, the firefly algorithm, iterative experiment design, and genetic algorithm-artificial neural network integration. Chapters detail modelling and optimisation. Slot and Pocket Milling on a prismatic component demonstrated the methods statistically. Many optimisation models have shown results in applicable situations. The conclusion includes final reflections and a summary of the work's importance. This effort should help the tool designer build a FLD with low elastic deformation and high-quality pieces.

I. INTRODUCTION

When the sum of the forces and moments acting on a rigid body is zero, the body is said to be in a state of static equilibrium. Constraining the workpiece's motion in all axes is made possible by the fixture system's static equilibrium. To do this, we use locators and clamps with a large enough clamping force and an appropriately designed fixture. This stops the workpiece from moving and allows the machining process to go more smoothly.

There are twelve possible motions for a rigid body in three-dimensional space. Therefore, prior to beginning machining, a workpiece must be completely limited by stopping all potential motions. Figure 1.1 depicts the twelve degrees of freedom, which include the forward and backward movement in the linear directions of the X, Y, and Z axes and the clockwise and anticlockwise rotations around the X, Y, and Z axes.

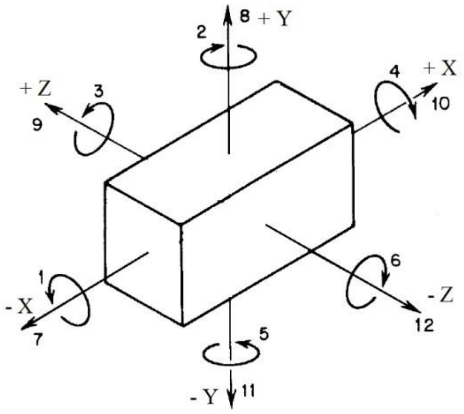

Figure 1 The Workpiece's Degrees of Freedom

In WFS, three, two, and one locator are positioned in the main, secondary, and tertiary planes, respectively, to arrest the nine degrees of freedom of the workpiece. Clamps are used to restrict motion in the positive X, negative Y, and negative Z directions, making this concept applicable to a system with a total of six degrees of freedom. Figure 1.2 depicts a locator setup using the 3-2-1 rule.

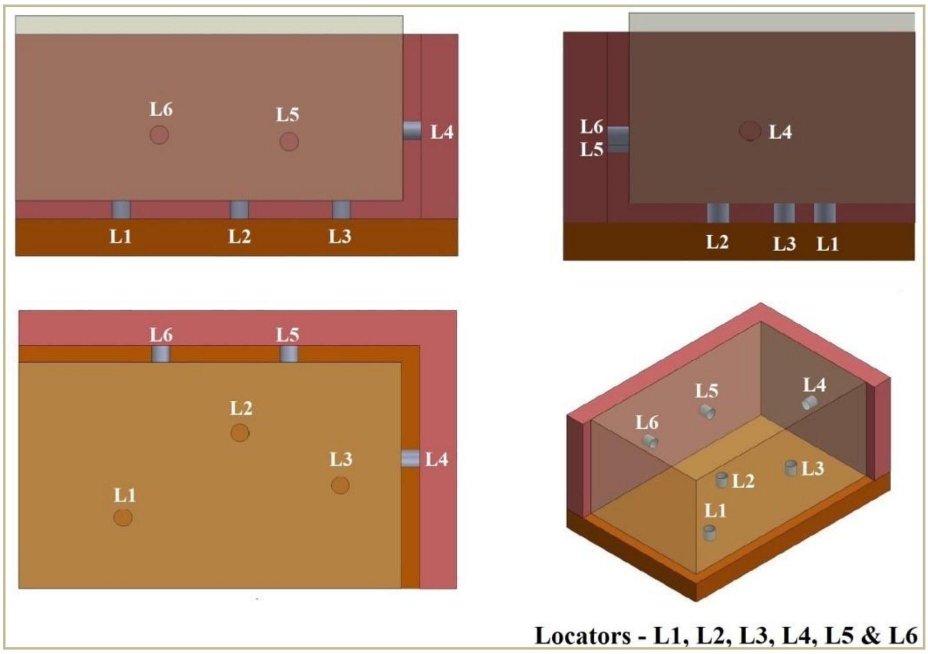

Figure 2 The 3-2-1 Positioning Rule

The 3-2-1 locating method is appropriate for attaching a prismatic workpiece with a minimum of fixturing.

II. ANALYSIS BY FINITE ELEMENTS

Many engineering issues simply do not have analytic solutions. A mathematical model or expression is the engineering answer since it can be used to calculate the value of the field variable at any point in the human body.

Analytical methods often fail when trying to address issues with irregular geometries, unusual materials, and tricky boundary conditions. Engineers often resort to numerical approaches because they give acceptable approximations to difficult issues. There are three common approaches. They do.

The Functional Difference Method (a) and the Functional Approximation Method (b)

Finite Element Analysis (c)

Popular engineering applications provided by current CAD/CAM systems include the Finite Element Method (FEM) and the Finite Element Analysis (FEA). It's because the finite element approach is the go-to when it comes to addressing engineering issues numerically. The approach is flexible enough to deal with a wide range of shapes and geometries (problem domain), materials, boundary conditions, and loads.

For today's complex engineering systems and designs, where closed-form solutions to governing equilibrium equations are often not accessible, the generality of the finite element approach is necessary. In addition, it is a useful tool for designers to do parametric design studies, which include thinking about several possible design situations (multiple forms, materials, loads, etc.), analyzing the results, and ultimately selecting the best design.

To produce approximations of solutions to engineering problems, the finite element method is a numerical methodology. To studying stresses in intricate air frame constructions, this approach has been embraced by the industry. Researchers and experts alike have come to favor this approach.

FEA PROCEDURE IN GENERAL

Following is a summary of the typical steps used while using FEA to resolve a continuum problem:

We must discretize the continuum.

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The issue domain is a continuum; thus, the finite element approach is useful for breaking it up into discrete, non-overlapping pieces. To do this, the continuum is substituted by a collection of nodes that, when joined in the right way, provide the elements. The finite element mesh is made up of a network of nodes and individual elements. There is a wide selection of element sizes and styles to choose from. Any combination of element types may be used by the analyst or designer to address a given challenge.

It is up to engineering discretion as to how many nodes and components may be employed in an issue. The cost of a finite element solution increases as the number of nodes and elements increases, since more memory space is required to acquire the solution.

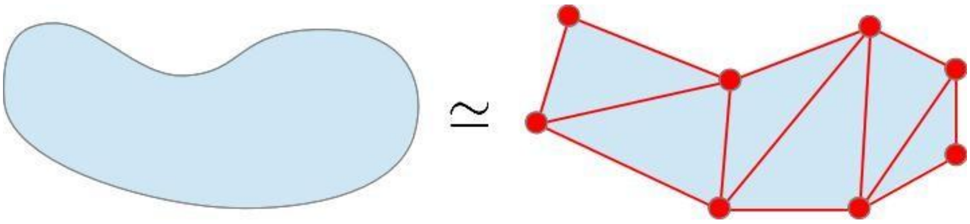


Figure 3 Discretization

Approximating a solution is the second step.

Within each element, a polynomial is used to approximation the variation of the unknown (called field variable) in the problem. It's possible for the field variable to be either a scalar (like temperature) or a vector. (For instance, both horizontal and vertical shifts) Since polynomials are simple to integrate and differentiate, they are often employed to approximatively solve problems across element domains. The degree of the polynomial is a function of the number of nodes in each element, the number of unknowns (field variable components) at each node, and the need for levels of continuity at the borders of the elements.

Element Matrix and Equation Growth,

The governing equilibrium equations are transformed from the continuum domain to the element domain in the finite element formulation. The direct technique, the variation method, the weighted residual method, and the energy method are used to determine the nodal and material equations.

The Fourth Element Matrices and Vectors Assembly

To acquire the global matrices and systems to algebraic equation, we put the matrices of the individual components together, considering their equilibrium and their equations. The system will need to be adjusted by including the boundary conditions before being solved. If they are not used, an incorrect solution or an intractable set of equations may emerge.

Node-Based Unknowns Solved

The field variable derivatives at the nodes are proved by solving the global system of algebraic equations using Gauss elimination techniques. It is feasible to acquire results for the original continuum that do not include nodes by solving the whole finite element problem.

Analyzing the Outcome

In the end, you'll evaluate the solution and the preceding step's findings to settle on a course of action for the design. Knowledge of engineering and finite element analysis is necessary for accurate interpretation of these findings.

The following flowchart illustrates the whole Finite Element Analysis process.

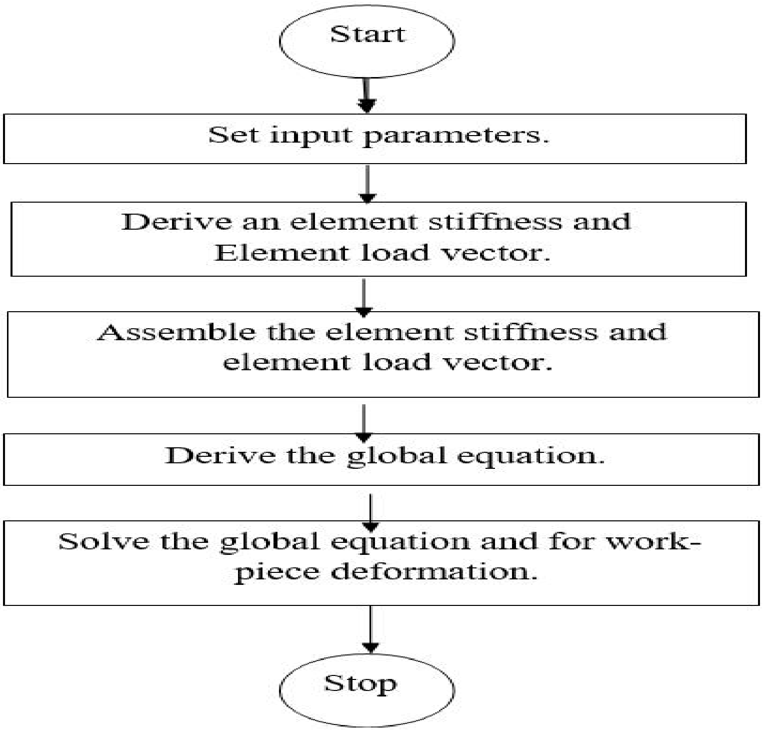


Figure 4 Flow chart of static analysis

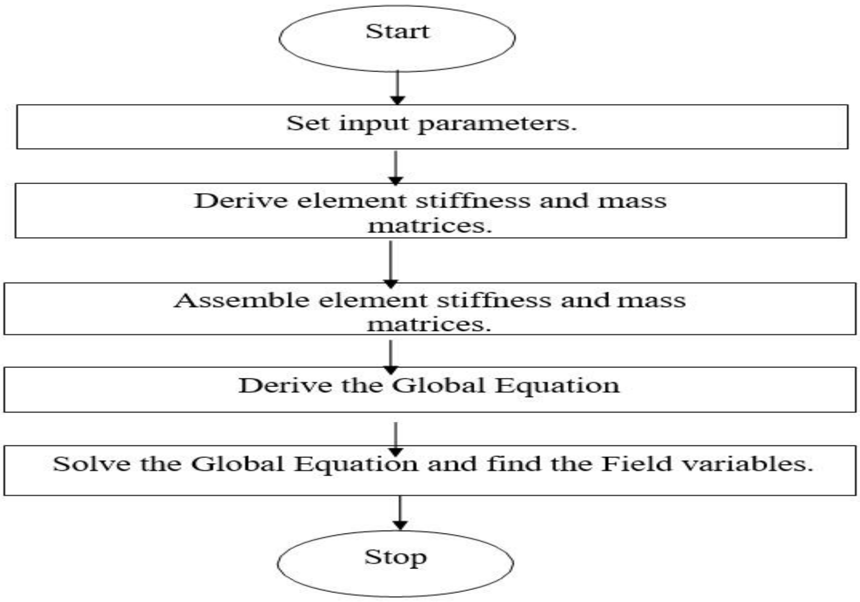


Figure 4 Flow chart of dynamic analysis

FORMULATION FOR FINITE ELEMENTS

For the finite element formulation, the static analysis makes the following assumptions:

The workpiece is a flexible body, whereas the fixture's components are rigid.

The m-embrace components are discretized from the 2-D work piece into triangles.

Each node has two degrees of freedom.

Only in-plane loads are counted towards the total external load.

Only plane tension is applied to the workpiece.

Only the horizontal direction is considered when calculating the dynamic reaction of the workpiece.

Only the stiffness perpendicular to the plane is considered for the workpiece.

The following assumptions are also employed in the dynamic analysis, in addition to those already mentioned.

Impulse and harmonic loads are two types of dynamic loads.

The mass matrix is derived with the consistent mass system in mind.

IV. RESULTS AND DISCUSSIONS

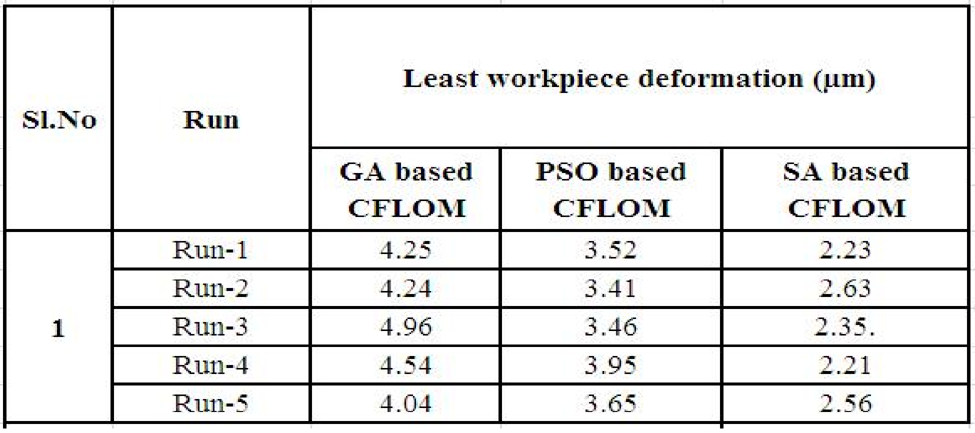
The objective function values (least work-piece deformation) and the convergence rates of GA-based CFLOM, PSO-based CFLOM, SA-based CFLOM, GA-based IFLOM, and PSO-based IFLOM are compared in this chapter.

Evaluating the Performance of GA, PSO, and SA-based CFLOM Objective Functions for Impulse Analysis

Values for the objective function while using GA based CFLOM, PSO based CFLOM, and SA based CFLOM are compared in Table 4.16. The objective function values derived by the GA-based CFLOM, the PSO-based CFLOM, and the SA-based CFLOM are all shown and compared in Figure 4.1. Convergence rates are compared in Figure 4.2 for the GA-based CFLOM, the PSO-based CFLOM, and the SA-based CFLOM.

The results of CFLOM with GA, PSO, and SA are shown in Table 1 and Figure 5, respectively. Fixture placement is optimized via the use of genetic programming, particle swarm optimization, and simulated annealing. Simulated annealing surpasses the evolutionary algorithm and particle swarm optimizations when it comes to the problem of optimizing the placement of fixtures. The convergence rate of the simulated annealing method is substantially greater than that of the genetic algorithm and particle swarm optimizations.

Table 1 shows a comparison of the objective function values for CFLOMs based on GA, PSO, and SA for Impulse analysis.



Sl.No	Run	Least workpiece deformation (µm)		
		GA based CFLOM	PSO based CFLOM	SA based CFLOM
1	Run-1	4.25	3.52	2.23
	Run-2	4.24	3.41	2.63
	Run-3	4.96	3.46	2.35.
	Run-4	4.54	3.95	2.21
	Run-5	4.04	3.65	2.56

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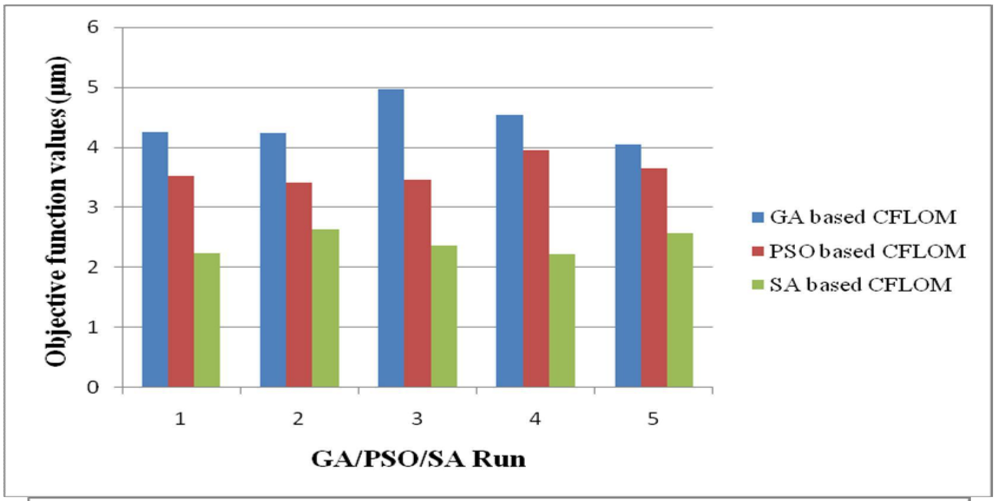
Figure 5 Analysing the value of the objective function in the context of Impulse using GA, PSO, and SA based CFLOM.



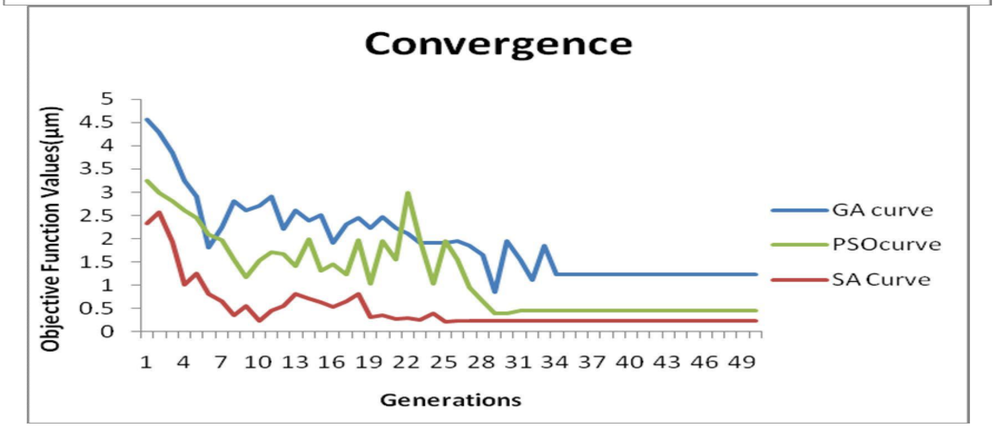


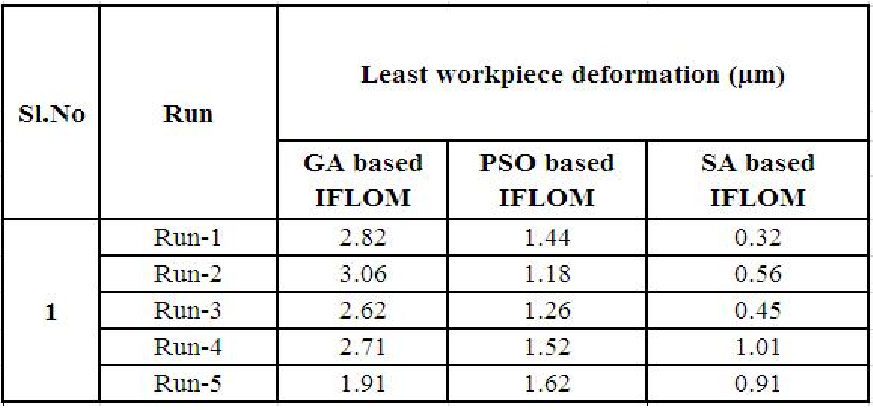
Figure 6 Analyzing impulses using CFLOM and comparing GA, PSO, and SA based convergence.

Value Comparison of Objective Functions in GA, PSO, and SA-based IFLOM for Impulse Analysis

Table 2 contrasts the objective function values produced by GA-based IFLOM, PSO-based CFLOM, and SA-based IFLOM. Figure 4.3 also depicts a contrast between the objective function values derived by the GA, PSO, and SA methods of solving IFLOM. The convergence rates of GA-based IFLOM, PSO-based IFLOM, and SA-based IFLOM are compared in Figure 4.4.

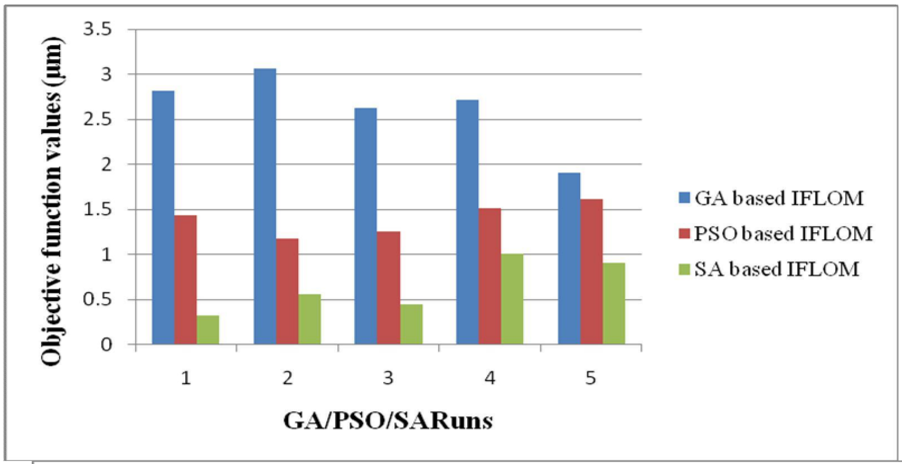
The results of IFLOM using genetic algorithms, particle swarm optimizations, and simulated annealing are shown in Table 2 and Figure 7. This issue's fixture layout optimization makes use of a genetic algorithm, particle swarm optimization, and Simulated Annealing. Simulated annealing surpasses the evolutionary algorithm and particle swarm optimizations when it comes to the problem of optimizing the placement of fixtures. Simulated annealing has a faster convergence rate than genetic algorithm and particle swarm optimizations.

Table 2 displays a value-based evaluation of GA, PSO, and SA-based IFLOMs for Impulse analysis.



Sl.No	Run	Least workpiece deformation (μm)		
		GA based IFLOM	PSO based IFLOM	SA based IFLOM
1	Run-1	2.82	1.44	0.32
	Run-2	3.06	1.18	0.56
	Run-3	2.62	1.26	0.45
	Run-4	2.71	1.52	1.01
	Run-5	1.91	1.62	0.91

Figure 7 Impulse analysis employing GA, PSO, and SA-based IFLOM with an emphasis on objective function value comparisons.



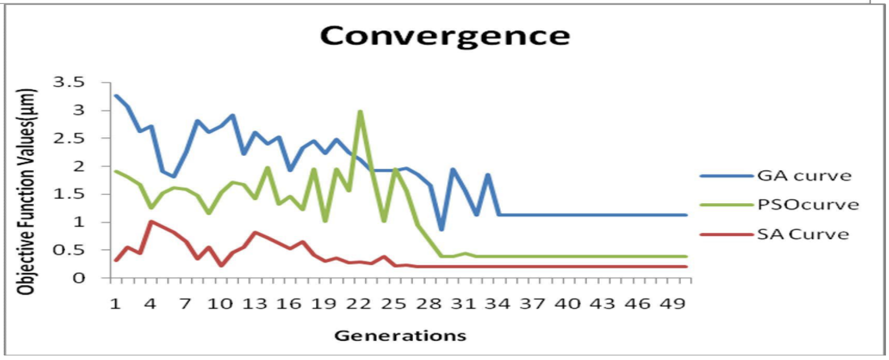


Figure 8 Analysis of Impulse data using a convergence comparison between GA, PSO, and SA-based IFLOM.

CONCLUSION

In this Paper, GA-based CFLOM, PSO-based CFLOM, and SA-based CFLOM were used to optimize the fixture configuration. For impulse analysis, we consider the GA-based IFLOM, the PSO-based IFLOM, and the SA-based IFLOM. Based on the results of comparing the integrated fixture layout optimizations technique to the continuous fixture layout optimizations method, we draw the following conclusions about the efficacy of these alternative approaches to solving fixture layout optimizations challenges. Fixture layout optimizations issues may be tackled with the use of a genetic algorithm, particle swarm optimizations, or simulated annealing. For fixture layout optimizations challenges, simulated annealing may provide better solutions at a quicker pace than genetic algorithm and particle swarm optimizations. Comparing the results of the continuous fixture layout optimizations approach with the integrated method, the latter is clearly superior. When compared to the continuous fixture layout optimizations approach, the convergence rate of the integrated method is higher.

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