

# Machine Design a Systematic Approach to Designing Mechanical Systems

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**Abstract---** Now a day fabricating enterprise are attempting to work on layered exactness, surface completion and efficiency during the multioperation machining process which thus decreases scrap rate and creation cost. Installation assumes a significant part to work on the machined surface nature of machining activity. The apparatus and its components are the fundamental devices to hold, secure and limit the workpiece during different activities in the machining system. The finders and clips are the components of the apparatus and their positions are known as installation design. The ill-advised apparatus format builds the machining vibration which thusly influences the precision of the completed item. The precisely planned apparatus format helps the originator to limit vibration during machining so the required machining exactness can be accomplished. Generally, in the processing system, the irregular commitment of multi-tooth shaper with workpiece brings about vibration of the apparatus workpiece framework which influences the surface completion of the machined workpiece which thus decreases the nature of machining activity. This vibration is expanded at a more significant level when the recurrence of energizing of multi-toothed processing shaper relates with any of the regular frequencies of the installation workpiece framework and it prompts the state of reverberation. The vibration increments under these circumstances, which decreases machining precision and surface completion of the machined workpiece. Consequently, the issues connected with the plan of installation design are to be tended to by perceiving the powerful way of behaving of the apparatus workpiece framework.

**Keywords---** Machining System, Optimization, Computer Aided Design.

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## I. Background

Modern manufacturing industries are attempting to work on layered precision, surface completion and efficiency during the multi-activity machining process which thusly lessens scrap rate and creation cost. These can be achieved utilizing apparatuses. Apparatuses are the work holding gadgets broadly used to lessen the process duration in computerized assembling, assessment, and gathering tasks (Utkin et al., 2017). In any case, the plan, manufacture and testing of apparatus consume a significant piece of new item improvement time. In a machining framework, the apparatuses are intended to be adaptable with the goal that the lead time can be decreased. The adaptable apparatus configuration allows speedy change of the current installation plans into the ones that meet for the necessities of new creation process. Generally, the adaptable fixturing frameworks might be furnished with customizable installation equipment and, apparatus plan and investigation programming (Crespi et al., 2018). The product helps with performing installation arranging, plan, and check capabilities in a brief time frame. The installation is a component of holding, finding and controlling the workpiece during machining activity to immobilize from its situation and it assumes a huge part in the majority of the cutting-edge assembling, gathering and review tasks. Apparatus components are finders, cinches, supports and installation body. Finders are accustomed to keeping the place of the workpiece in the apparatus by controlling the movement of the part. Clasp powers are applied to the braces to immobilize the workpiece in the apparatus against machining powers. Deformity of the workpiece because of cutting and machining powers is limited utilizing support components. Apparatus body is utilized to keep up with the spatial connection between the installation components during the machining system (Mohajer et al., 2017). Installation components are significantly diminishing the arrangement time and work cost prior to machining activity. Besides, they increment the precision of the machining, decline the cost of value control and impact the machine instrument computerization. The dependability of the workpiece during machining process is accomplished by setting the apparatus components fittingly in their area to compel the workpiece.

## II. Literature Review

Generally, in the machining operation, elements of fixture employed to constrain the workpiece in unique and repeatable position. They put on the outer layer of the workpiece which thusly shapes the machining apparatus format. The primary goal of planning the installation design is to make apparatus setups to get the parts unequivocally during machining processes. Further, it is fundamental for machining the item and interaction plans while keeping an ideal plan for capability and primary execution (Adegbite et al., 2023). A legitimate apparatus format configuration guarantees the workpiece to be situated definitively in its situation concerning the cutting device. Subsequently, apparatus components improved machining precision and decreased cost of value control of the machined part. Further, it maintains the uniform quality of production processes and permits the cutting tool to vary the machining parameters thereby machining time reduced and productivity increased. The fixture layout should be designed at an initial stage by considering the feasibility of the machining system. Any alteration in the fixture layout design in the later stages increases the unit cost. The layout of fixture elements significantly influences the accuracy which in turn affects the productivity and assembly of parts. It uncovers that the apparatus format configuration assumes an essential part in machining the parts with the necessary degree of precision (Vergnano et al., 2020). Hence, an automated fixture layout design is required to machine the parts with greater accuracy in the machining system. Though the manufacturing industries employ highly experienced professionals to design fixtures, the tasks are complex and require huge time for intricate workpiece geometries. Further, the issues related to quality, cycle time and production cost are to be addressed. Though Computer Aided Design (CAD) is used to design a fixture, lack of well-organized approach towards design performance evaluation leads to numerous problems:

- The failure to guarantee the quality of design before production,
- Increase in cycle time of fixture design, fabrication, and testing,
- poor performance evaluation of fixture design.

Consequently, it is fundamental to foster apparatuses that kill expensive, tedious experimentation plans. The Computer Aided Fixture Layout Design (CAFLD) can coordinate the ideas in computer aided design and installation format plan to shape an organized technique to find a plausible answer for convoluted issues in installation design plan (Camburn et al., 2015). The principal objective of this exploration work is to foster a CAFLD system to decide the ideal installation design for under powerful machining conditions.

## III. Analysis and Design

The machining fixture layout is commonly designed by modeling and analyzing the interactions. The workpiece geometry that is subjected to machining has a three-dimensional profile and is difficult to be modeled and analyzed using simple mathematical models. Hence, these models are not able to completely describe the real conditions and have the limitation of handling few variables (Kannengeisser & da JA, 2018). However numerical methods are widely used to overcome the above said difficulties and have the ability to model and analyze complex conditions. Finite Element Method (FEM) is one of the robust numerical approaches and suitable to handle and analyze the vibrations. In FEM, the complicated three-dimensional geometry is represented by an approximately equivalent and finite number of structural elements possessing a finite number of degrees of freedom, which are interconnected at nodes. The size of the element chosen is small to approximate the deformation within the elements with lower order polynomials. The interaction between fixture-workpiece and the cutting tool has been studied by analyzing the modeled fixture-workpiece system. Four analyses namely geometric, kinematic, force and deformation analysis are commonly employed by the researchers to design the fixture layout. Geometric analysis is used to determine the number of locators and clamps needed during machining operation by accounting the interference between the fixture-workpiece and cutting tool. Kinematic analysis is used to analyze the motion of the workpiece during the machining process. Force analysis is employed to determine the minimum clamping forces required for the machining fixture. Deformation analysis is used to determine the maximum deformation of the workpiece during machining. This analysis is used to accurately design the fixture layout which minimizes workpiece deformation thereby increasing the accuracy of the machined part.

### ***Modeling and Analysis of Fixture-Workpiece System***

The machining vibration plays a vital role in influencing the dimensional and form errors in the finished product which in turn increases the rejection rate (Houssin et al., 2010). About 20% to 60% of machining error

caused by improperly placed fixture elements affects the product quality. This machining vibration is controlled by placing fixture elements in the exact location. In general, around 20% to 30% of the total cost of manufacturing system incurred by design and manufacturing of fixture and it is also a tiresome and time-consuming work. In the recent years, computer simulations are used in the new product development to reduce cycle time and minimize the product development cost. In modern manufacturing industries give much attention to computer simulation than fabricating the prototype because of the closeness of simulation results with experimental results. In fixture design and analysis, computer simulation is used to perform deformation, geometric, kinematic and force analysis. Further, the dynamic analysis is also performed using computer simulation to determine the dynamic response of the machining system. It is necessary to determine optimal fixture layout to minimize workpiece vibration and reduce dimensional and form errors. These reasons motivated to do the research work in fixture layout optimization under dynamic conditions.

The modular examination is led to figure 1 the unique way of behaving (regular frequencies) of the workpiece (Liu et al., 2015). The normal recurrence of the workpiece is affected by math, the material property of the workpiece and the places of finders and braces. Subsequently, the regular recurrence can be adjusted utilizing the place of finders and clasps and material expulsion which modifies the math. machined workpiece will be more. Thus, it is fundamental to decrease layered blunder and increment machining exactness by having the bigger effect between regular recurrence and energizing recurrence.

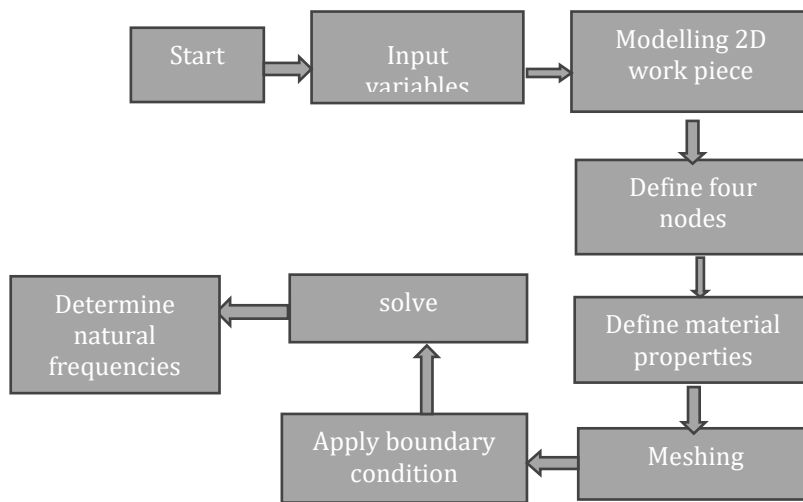


Figure 1: Block Diagram of Proposed Model

The proposed methodology utilizes the advantages of FEM and evolutionary techniques. FEM is used to predict the dynamic behavior of the fixture-workpiece system and the evolutionary techniques are employed to determine the optimal fixture layout. A frequency-based approach is employed to minimize the vibration which uses the difference between natural and exciting frequency of the fixture-workpiece system. The FEM is mainly used to find the difference between these frequencies of the system. Two unique transformative procedures specifically Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) are utilized to boost the distinction between these frequencies by advancing the machining apparatus format. The exhibition of GA and PSO on installation format enhancement is thought about. The examination of results presumes that PSO is the most suitable methodology than GA in accomplishing improved results.

### Genetic Algorithm

Hereditary calculations imitate the normal determination process and are generally utilized for taking care of nonlinear enhancement issues. GA administrators, for example, determination, hybrid and change are used to give the top-notch answers for the issues having huge arrangement space. In this exploration work, the places of apparatus components are addressed as parallel coded strings and they are decoded into genuine worth. These qualities are taken as plan factors and put away into the ANSYS data set. After that the goal capability values (contrast between regular recurrence and energizing recurrence) are determined utilizing ANSYS. Then, multiplication activity involves choice administrator as roulette wheel determination in which the arrangements are chosen from the irregular populace which is relative to its wellness values. The wheel comprises of number of sections equivalent to the populace size and the size of each fragment relies upon the wellness esteem. An irregular number is utilized to pick the chromosome from the populace and to shape the

mating pool. This strategy is rehashed until the size of the mating pool equivalents to the size of the populace. The point of generation is to suggest better strings have higher possibility of choice. Nonetheless, the substandard strings might get disposal from the determination.

### Particle Swarm Optimization

PSO is a metaheuristic approach designed by Kennedy, and Eberhart. It is enlivened by the social way of behaving of bird running or fish tutoring. It is likewise a populace-based search procedure used to tackle the issues including huge arrangement space. In this calculation, the learning factors LF1 and LF2 are utilized as control boundaries which impact the union of PSO. These boundaries are to be differed somewhere in the range of 1 and 4 to dissect their exhibition on the course of combination.

## IV. Requirement Resources and Results

In this examination work, FEM is used to dissect the unique way of behaving of the apparatus workpiece framework during end processing activity and the machining device way is discretized into a few burden steps. The principal objective of the examination is to process the regular frequencies of the apparatus workpiece framework for different burden steps and the astonishing recurrence of the processing shaper. Instrument ANSYS 15.0 is utilized to direct the modular investigation and to register the normal frequencies of the apparatus workpiece framework. Transformative procedures of GA and PSO are utilized to expand the distinction between normal recurrence of the fixtured workpiece and energizing recurrence of the shaper to limit the vibration on the workpiece. The coding of GA and PSO are created utilizing MATLAB programming. FEM and transformative procedures are communicated through ANSYS 15.0 and MATLAB to track down the ideal installation format.

The impact of material evacuation has been concentrated by plotting the diagram between the heap steps and the principal normal frequencies of arbitrarily produced designs and is displayed in Figure 2. It is seen that there is a slight expansion in normal recurrence during the beginning phases of the material evacuation while a minor reduction is seen during the last stages. Consequently, it is affirmed that the impact of material expulsion affecting the progressions in regular recurrence is because of the nonstop difference in mass and firmness of the workpiece.

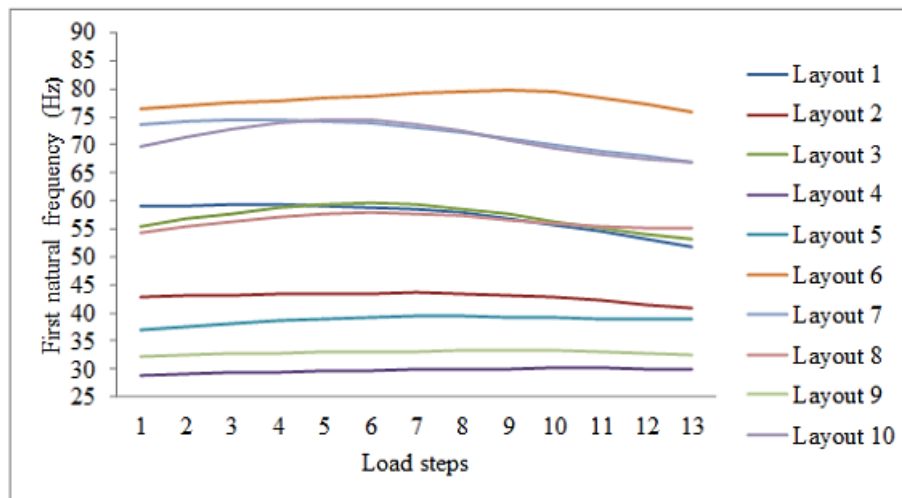


Figure 2: Effect of Material Removal on Natural Frequency

Then, at that point, the primary regular recurrence which is closer to the thrilling recurrence among all heap steps is chosen and the contrast between these two frequencies is noted as the goal capability. The closeness of these frequencies boosts the bothersome vibration and coming about layered mistakes on the machined workpiece. Consequently, the vibration of the workpiece can be limited by enhancing the goal capability and it very well may be achieved by deciding the proper situation for the finders and clips.

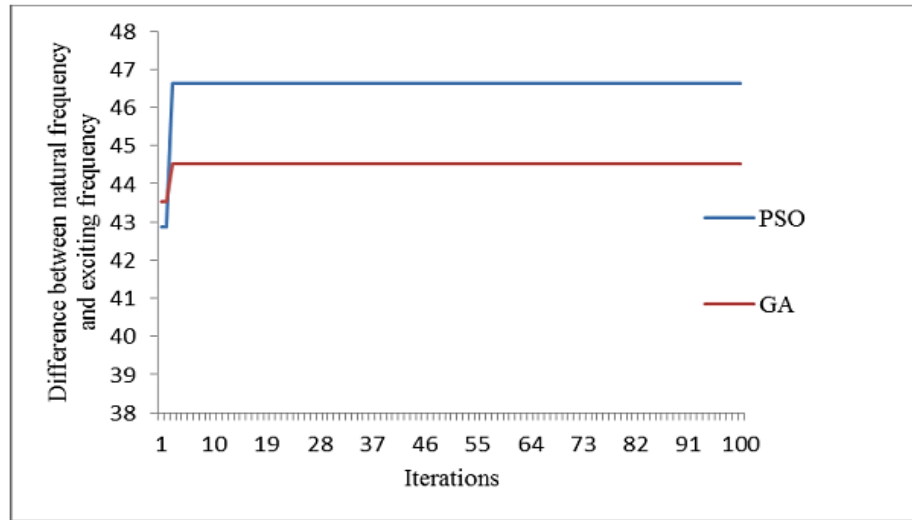


Figure 3: Comparison of Convergence of GA and PSO

In figure 3, the utilization of GA and PSO for the machining installation design enhancement during end-processing activity has been carried out for a basic 2D installation workpiece framework. The outcomes show that the mix of PSO with FEM creates better compared to that of GA. It empowers the utilization of PSO for apparatus design plan issues including different machining conditions.

## V. Conclusions

In the machining activity, precision and item quality are improved by limiting the machining blunders on the machined workpiece. The machining mistakes can be diminished by limiting the vibration of the workpiece. A precisely planned apparatus design empowers to limit the workpiece vibration so the expected resistance particulars on the machined workpiece can be ensured. The recurrence-based approach has been produced for upgrading the machining installation design to limit the workpiece vibration during the machining system. The proposed procedure has been executed on 2D apparatus - workpiece framework by incorporating FEM and transformative strategies of GA and PSO. The 3-2-1 finding rule has been applied to figure least number of apparatus components to control the development of the workpiece. The apparatus format around the workpiece calculation has been demonstrated and dissected utilizing ANSYS 15.0 and it has been interacted with MATLAB programming to run the enhancement calculations. ANSYS 15.0 computes the contrast between regular recurrence of the workpiece and invigorating recurrence of the shaper for every apparatus design produced by the enhancement calculations. GA and PSO based enhancement calculations have been utilized to augment the distinction between these frequencies via looking through the encouraging apparatus designs.

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