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Extension of VIKOR Method to Find an Optimal Layout for Fixture's Supporting Points in Order to Reduce Work Piece Deformation

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ABSTRACT

In automotive industry fixtures have a direct effect on product manufacturing quality, productivity and cost, as a result fixtures, particularly welding fixture, play a crucial role in the auto industry. The fixture is a special tool for holding a work piece in proper position during manufacturing operation, so in the phase of the fixture design process positioning pins and surfaces are used to make sure that the work piece is positioned correctly and remain in the same position throughout the operation. The less positioning surfaces leads to the less work piece deformation. The aim of this paper is to find optimal number of positioning surfaces using VIKOR method with Shanon entropy concept to extract and utilize objective weights. VIKOR, means multi-criteria optimization and compromise solution, is a modern approach that has preference over other MCDM methods. An empirical example is presented to demonstrate an application of mentioned method.

Keywords : Fixture design; VIKOR method; MCDM; ABAQUS; Supporting points.

1 INTRODUCTION

THE automotive industry is a wide range of companies and organizations involved in the design, development, manufacturing, marketing, and selling of motor vehicles [1]. The automobile industry is one of the leading industries at the global level. It plays a crucial role in the development of the global economy because of the high revenues and increased customer demands. The automobile industry helps to foster economic development of the country; therefore, it is widely recognized as a major economic sector [2]. The automobile industry has become more competitive as the fast trend growing automobile industry in Asia has drawn attention. Asia has been acknowledgement as a potential growth area for the automobile industry. A brands new car publication has led to increased competition, substantial price cuts and lower margins in the automobile industry [3]. These relationships are not confined to the pursuit of short-term economic imperatives cost reduction but embrace innovations in design and technology, creative research and development and quality improvement and after sale services [4].

Fixtures are used to securely locate (position in a specific location or orientation) and support the work, ensuring that all parts produced using the fixture will maintain conformity and interchangeability. Using a fixture improves the economy of production by allowing smooth operation and quick transition from part to part, reducing the

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requirement for skilled labor by simplifying how work pieces are mounted, and increasing conformity across a production run [5]. A fixture's primary purpose is to create a secure mounting point for a work piece, allowing for support during operation and increased accuracy, precision, reliability, and interchangeability in the finished parts. It also serves to reduce working time by allowing quick set-up, and by smoothing the transition from part to part [6]. The components that hold and locate the work piece are called fixture elements. The arrangement of these fixture elements is very important to reduce the errors in manufacturing process. According to Prabhaharan et al. the position of the fixturing elements in the fixture is called fixture layout, and the layout, which minimizes the work piece deformation is called optimal fixture layout [7]. Economically speaking the most valuable function of a fixture is to reduce labor costs. Without a fixture, operating a machine or process may require two or more operators; using a fixture can eliminate one of the operators by securing the work piece [6].

The most usual optimization methods implemented are mathematical programming approaches, penalty function methods, simulated annealing, genetic algorithm, and ant colony algorithm. The mathematical programming methods can be classified as linear programming (LP), linear & quadratic integer programming (LQP), dynamic programming (DP), goal programming (GP) and sequential quadratic programming (SQP) [8]. The work piece deformation can be minimized by finding the appropriate position for the locators and clamps. Thus, it is necessary to model the complex behavioral relationship that exists in the fixture–work piece system. Krishnikumar used response surface methodology to model the relationship between position of locators and clamps and maximum deformation of the work piece during end-milling, and then the developed model has been optimized by genetic algorithm and particle swarm optimization [9]. In machining fixtures, minimizing work piece deformation due to clamping and cutting forces is essential to maintain the machining accuracy. This can be achieved by selecting the optimal location of fixturing elements such as locators and clamps. S. Selvakumar et al. proposed artificial neural networks (ANN)-based algorithm with design of experiments (DOE) to design an optimum fixture layout in order to reduce the maximum elastic deformation of the work piece caused by the clamping and machining forces acting on the work piece while machining [10]. Bo Yang et al. proposed a new approach to optimizing the sheet metal fixture locating layout based on the “N-2-1” locating principle by coupling cuckoo search algorithm with finite element analysis [11]. Firstly, we analyze the deterministic localization model and static equilibrium condition by introducing related uncertainty errors. Then, using the Monte Carlo Method (MCM), we randomly assign the fixture parameters from corresponding probability distributions. Further, we compute the norm of position error of critical point according to the principles of minimum potential energy and the Nonlinear Least Square Method (NLSM) [12]. Xue Bai et al. described a new approach based on Memetic Algorithm (MA) to multi-objective fixture layout optimization, considering both location accuracy and stability [13]. Wang et al. presented a methodology for weakly-rigid parts based on the N-2-1 ($N > 3$) locating principle. An optimization algorithm combines finite element analysis and nonlinear programming methods to find the optimal number and position of the locating points in order to minimize the assembly deformation [14]. Cong Lu proposed an approach to optimizing fixture layout for the sheet metal work piece based on the 4–2–1 locating scheme. Firstly, three fixture locating points on the primary datum surface are optimized with genetic algorithm based on the rigid model considering the robustness and the geometry stability. Then based on finite element analysis, a back propagation neural network model is built to predict the deformation of the sheet metal work piece under different fixture layouts and different fixture locator errors, and a genetic algorithm is used to find the optimal position of the fourth fixture locator based on the neural network prediction model [15]. We propose a new fixture layout optimization method N-3-2-1 for large metal sheets that combines the genetic algorithm and finite element analysis. The objective function in this method is to minimize the sum of the nodal deflection normal to the surface of the work piece [9]. Tao et al. presented a computational geometry approach for arbitrarily shaped work pieces. All the possible clamping points are automatically found, and then optimal clamping points are chosen from a feasible clamping region. The method is verified by case studies [16]. Liao et al. presented a technique for fixture layout optimization subjected to the dynamic conditions. The parameters affecting the fixturing stability are analyzed. These parameters are the clamping force magnitude, the application sequence, and the placement of the fixturing clamps. The deformation of a flexible work piece under clamping and machining loads is estimated under dynamic conditions [17]. Li et al. presented an approach for fixture layout and clamping force optimization. This approach considers the work piece dynamics during machining. The objective function of this approach is to minimize the maximum positional error at the machining point during machining. An iterative fixture layout and clamping force optimization algorithm yields the best results that are verified by simulations [18]. Li et al. developed a fixture configuration methodology based on a new proposed locating scheme for sheet metal laser welding. The case study of automotive assembly is investigated by applying the fixture configuration design method [19]. Ma et al. proposed a new method for compliant fixture layout design using a topology optimization method. The objective function is to minimize the overall deformation of the work piece. Both 2-D and 3-D numerical examples are presented to verify the effectiveness of the proposed approach [20].

2 MULTI CRITERIA DECISION- MAKING (MCDM)

Multi criteria decision-making (MCDM) process provides the selection of the most advantageous choice for an alternative from a large set of possible alternatives. MCDM is considered as the process of determining the best feasible solution in the presence of multiple, potentially conflicting criteria (design characteristics).Various approaches have already been developed to help organizations in order to choose the design characteristics for a product and interact the product with the customer [21]. In MCDM problems, since that the valuation of criteria leads to diverse opinions and meanings, each attribute should be import with a specific importance weight [22].

3 SHANON ENTROPY METHOD

To obtain a better weighting system, we may categorize weighting methods into two categories: subjective methods an objective methods [23]. While subjective methods determine weights solely based on the preference or judgments of decision makers, objective methods utilize mathematical models, such as entropy method or multiple objective programming, automatically without considering the decision makers' preferences. The approach with objective weighting is particularly applicable for situations where reliable subjective weights cannot be obtained [24].

4 VIKOR METHOD

Opricovic S., introduced the VIKOR method as well-known MCDM technique which emphasized on select and rank of alternatives sets of conflicting criteria, in recent years this technique more evolved by scholars [25]. The VIKOR method was developed for multicriteria optimization of complex systems. It determines the compromise ranking-list, the compromise solution, and the weight stability intervals for preference stability of the compromise solution obtained with the initial (given) weights. This method focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. It introduces the multicriteria ranking index based on the particular measure of ''closeness'' to the ''ideal'' solution[26]. Assuming that each alternative is evaluated according to each criterion function, the compromise ranking could be performed by comparing the measure of closeness to the ideal alternative. The multicriteria measure for compromise ranking is developed from the Lp-metric used as an aggregating function in a compromise programming method [27],[28].

The various *m* alternatives are denoted as $A_1, A_2, \ldots, Am$. For alternative A_i, the rating of the *jth* aspect is denoted by f_{ij} ($i=1,2,\ldots,m; j=1,2,\ldots,n$), i.e., f_{ij} is the value of *jth* criterion function for the alternative A_i, *n* is the number of criteria. Development of the VIKOR method is started with the following form of Lp-metric:

$$L_{p,i}=\left\{\sum_{j=1}^{n}\left[w_j\left(f_j^*-f_{ij}\right)/\left(f_j^*-f_{ij}^-\right)\right]^p\right\}^{1/p} \quad , \quad 1\le p\le\infty \tag{1}$$

In the VIKOR method $L_{1,i}$ (as S_i) and $L_{\infty,i}$ (as R_i) are used to formulate ranking measure. The solution obtained by min S_i is with a maximum group utility (''majority'' rule), and the solution obtained by min R_i is with a minimum individual regret of the opponent.

The VIKOR procedure has the following steps:

Step 1

Determine the best f_j^* and the worst f_j^- values of all criterion functions, $j=1,2,\ldots,n$; if the *jth* function is benefit:

$$f_j^* = Max\left(f_{ij}, i = 1,...,I\right), f_j^- = Min\left(f_{ij}, i = 1,...,I\right) \tag{2}$$

If the *jth* function is cost:

$$f_j^* = Min\left(f_{ij}, i = 1,...,I\right), f_j^- = Max\left(f_{ij}, i = 1,...,I\right) \tag{3}$$

Step 2

Compute the values S_i and R_i , $i = 1,2,...,I$, by the relations:

$$S_i = \sum_{j=1}^{n} w_j \left(f_j^* - f_{ij}\right) / \left(f_j^* - f_{ij}^-\right) \tag{4}$$

$$R_i = Max\left[w_j \left(f_j^* - f_{ij}\right) / \left(f_j^* - f_{ij}^-\right)\right] \tag{5}$$

where w_i are the weights of criteria, expressing their relative importance.

Step 3

Compute the values $Q_i, i = 1,2,...,I$, by the following relation:

$$Q_i = \vartheta\left(S_i - S^*\right) / \left(S^- - S^*\right) + \left(1 + \vartheta\right)\left(R_i - R^*\right) / \left(R^- - R^*\right) \tag{6}$$

where

$$S^* = MinS_i, S^- = MaxS_i \tag{7}$$

$$R^* = MinR_i, R^- = MaxR_i \tag{8}$$

and v is introduced as a weight for the strategy of ‘‘the majority of criteria’’ (or maximum group utility), whereas $1-v$ is the weight of the individual regret. These strategies could be compromised by $v = 0.5$, and here v is modified as $= (n+1)/2n$ (from $v + 0.5(n-1)/n = 1$) since the criterion (1 of n) related to R is included in S, too.

Step 4

Rank the alternatives, sorting by the values *S*, *R* and *Q*, in decreasing order. The results are three ranking lists.

Step 5

Propose as a compromise solution the alternative A' which is the best ranked by the measure *Q* (minimum) if the following two conditions are satisfied:

C1. “Acceptable advantage”: $Q(A'' - Q(A')) \geq DQ$. Where A'' is the alternative with second position in the ranking list by *Q*; $DQ = 1/(J-1)$. *m* is the number of alternatives.

C2. “Acceptable stability in decision making”: The alternative A' must also be the best ranked by *S* or/and *R*. This compromise solution is stable within a decision making process, which could be ‘‘voting by majority rule’’ (when $v > 0.5$ is needed), or “by consensus” v about 0.5, or “with veto” ($v < 0.5$). Here, v is the weight of the decision making strategy ‘‘the majority of criteria’’ (or ‘‘the maximum group utility’’). If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:

- Alternatives A' and A'' if only the condition C2 is not satisfied
- Alternatives $A', A'', ..., A^{(M)}$ if the condition C1 is not satisfied; $A^{(M)}$ is determined by the relation $Q(A^{(M)} - Q(A'')) \prec DQ$ for maximum M (the positions of these alternatives are "in closeness").

The best alternative, ranked by *Q*, is the one with the minimum value of *Q*. The main ranking result is the compromise ranking list of alternatives, and the compromise solution with the ''advantage rate''. VIKOR is an effective tool in multi-criteria decision making, particularly in a situation where the decision maker is not able, or does not know to express his/her preference at the beginning of system design [29]. The obtained compromise solution could be accepted by the decision makers because it provides a maximum utility of the majority (represented by min *S*), and a minimum individual regret of the opponent (represented by min *R*). The measures *S* and *R* are integrated into *Q* for compromise solution, the base for an agreement established by mutual concessions.

The extended VIKOR method is illustrated in Fig.1.

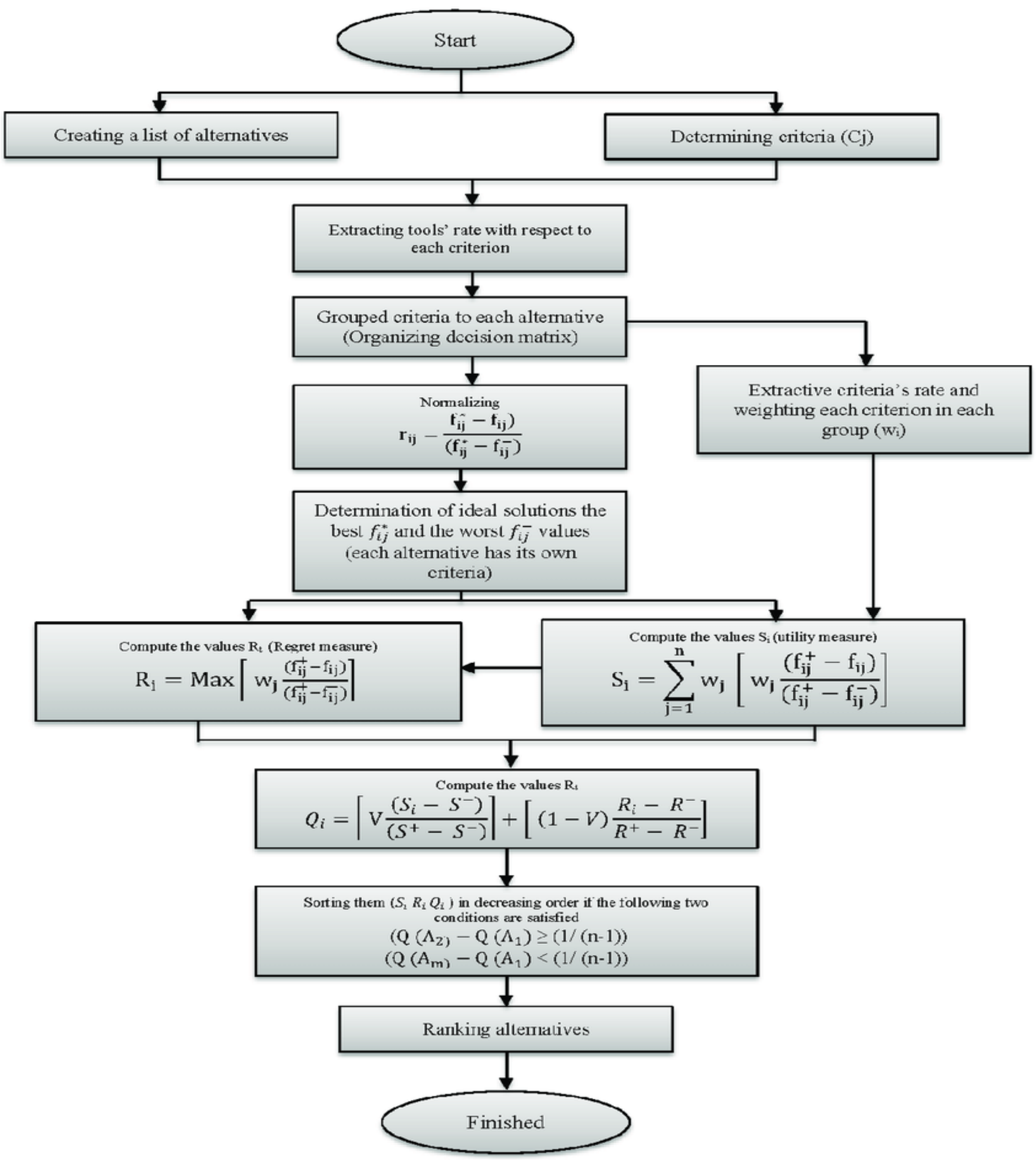

Fig.1
Diagram of modified VIKOR technique adopted from [29].

5 OBJECTIVES OF PROBLEM

5.1 Objectives of fixture design for flexible work pieces

1. Refusing work piece deformation while it is located on the jig.
2. Refusing work piece deformation while fastening fixtures.
3. Refusing work piece deformation caused by work operations (spot welding).
4. Clash refusing.
5. Refusing work piece deformation while it is taken from the jig.
6. Positioning accuracy and validation of work pieces relative to each other during the process.
7. Geometric quality produced work piece.

Prioritizing objectives of fixture design for flexible work pieces:

- According to above-mentioned objectives, it is found that none of these objectives have the same weights and importance in production process and for optimal performance they need to be prioritized and the weights of them are given. Based on design and production standards and qualitative studies the priorities is sorted out as follow:
- First priority: geometric quality produced work piece.
- Second priority: positioning accuracy and validation of work pieces relative to each other during the process.
- Third priority: refusing work piece deformation while it is located on the jig.
- Fourth priority: refusing work piece deformation while fastening fixtures.
- Fifth priority: refusing work piece deformation caused by work operations (spot welding).
- Sixth priority: refusing work piece deformation while it is taken from the jig.
- Seventh priority: clash refusing.

5.2 Objectives review

Since the priorities of the objectives described previously are common in many design sections and the number of them is quite a lot, it is necessary to combine some of them. The first and second priorities depend on fourth section of fixture design and the way of how to design for every component in them are really crucial. This paper does not go further than second section of fixture design so there is no way to enter those mentioned objectives directly in this study. The third priority can be considered as the first and vital optimization objective. If the third priority is carried out in a right way, it can be say with certainty that it covers partly first and second priorities and almost completely fourth, fifth and sixth priorities too. Seventh priority have been a considerable discussion all the time and has a high impact upon final design phase. Hence two essential objectives can be accounted for optimizing as follow:

- First objective: refusing work piece deformation while it is located on the jig.
- Second objective: clash refusing.

6 KEY MEASURE POINT (KMP)

Key measure point can be used to determine the deformation measurement of work piece especially to assemble structures with low rigidity. In fact these point are control points and no constraint is imposed on them. In this paper, in order to accelerate the speed of computation by ABAQUS software, border and central points are taken as KMPS. Here the residual strain and strain hardening caused by pressing process in low rigidity components is not taken in consideration.

7 METHODOLOGY

According to this optimization problem, the processes can be explained as following steps:

1. Proposed mesh is applied according to the mesh production principles and a pair of support points are located within confidence intervals in feasible region then these points are numbered 1 to *N*.

2. $F(\vec{X})$ is computed under gravity, If it is too big then support points need to be balanced, therefore, they are controlled within confidence intervals.
3. Supporting points $\{1,...,N\}$ are eliminated in order. After eliminating every point, $F(\vec{X})$ is calculated and the point that has the least impact is removed. Now $N-1$ supporting points are left.
4. Step 3 is repeated until a certain stopping criterion is found.

Owning to there is no function that has closed form to $F(\vec{X})$, g function can be estimated by finite-difference methods as follow:

$$g_i = \frac{F(X+\Delta X_i)-F(X)}{\Delta X_i} \tag{9}$$

where ΔX_i is presented as:

$$\Delta X_i = [0,...,\delta_i,...,0]^T \tag{10}$$

Now the situations and numbers of all of positioning points are selected.

8 EMPIRICAL EXAMPLE

In this section optimization procedure is defined using a piece of sheet metal with the dimensions 1.5×350×400 mm^3. the sheet metal's parameters are shown in Table 1. We have 9 KMP and 12 Preliminary positioning points.

Table 1
Sheet metal's parameters.

Parameters	Amount
Mass density	103×6.98 (*kg/m3*)
Young's modulus	105×2 (*MPa*)
Poisson's ratio	0.23

It is assumed that there are some work limitations in Fig. 2. There is welding process, transferring shuttle and matching zones in red, yellow and green areas respectively. In fact it is impossible to put supports in these areas. For that reason, the accessibility to points and areas to hold work piece is limited to colorless areas.

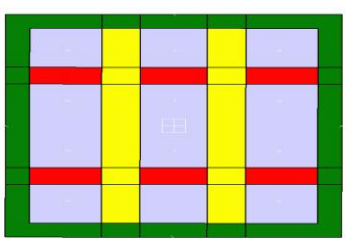

Fig.2
Areas with limitation to supporting points selection.

There is a relation between dimension of KMPs and design requirements. It means if some points have more design sensitivities are considered to be KMP. In this case study central and corner points of transverse and longitudinal edges and also intermediate points of given sheet metal are considered as KMPs.

According to mentioned assumptions about positioning points of the work piece as well as limitations and requirements, the most required points are selected by application of ABAQUS software as shown in Fig. 3. It should be noted that the first intervals are chosen based on primary finite element analysis. The most required points in this example are 12 and defined intervals are steady. There are a lot of things that have an influence on selection process such as spot welding region, welding guns pathways and other equipment considered to introduce positioning points in the initial design.

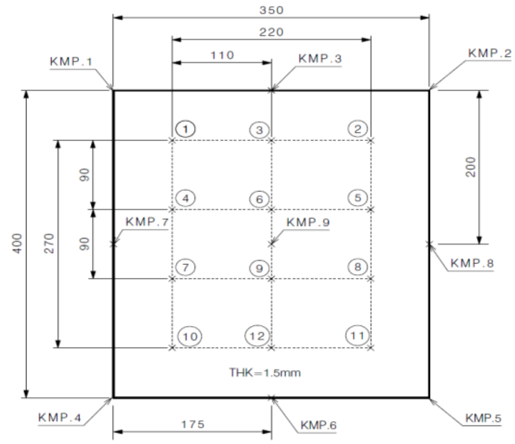

Fig.3
Dimensions of the model location of KMPs.

Constrain of positioning point (x_j, y_j) is as follow:

$$0 \le x_j \le 400 \qquad j = 1,2,...,12 \tag{11}$$

$$0 \le y_j \le 350 \qquad j = 1,2,...,12 \tag{12}$$

Deformation constraints in the normal direction of every KMP.

$$\left|U_i(\vec{X})\right| \le \Omega = 0.02mm \qquad i = 1,2,...,L,(L = 9) \tag{13}$$

As it shown in Fig. 4 , after conducting analysis of given model, the most acceptable deformation in the initial layout is less than 0.02 *mm* (0.010188 *mm*).

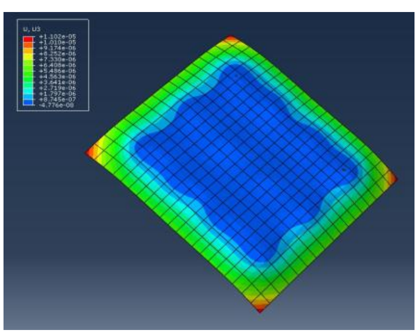

Fig.4
Initial analysis.

1. The elimination of every positioning point is done in the first step.
2. The amount of deformation in the normal direction of every KMP is computed.
3. If the condition of $\Omega \le 0.02mm$ for each point is satisfied, then go for the next step, otherwise the process will finish.
4. The best point in order to eliminate is found using VIKOR method.
5. The best point is eliminated.
6. Replicate this process until the condition of $\Omega \le 0.02mm$ is not satisfied.

In this section all of 12 pints are available and the process is started in the nods' numbers sequence. The summary of the accomplished results are provided in Fig. 5.

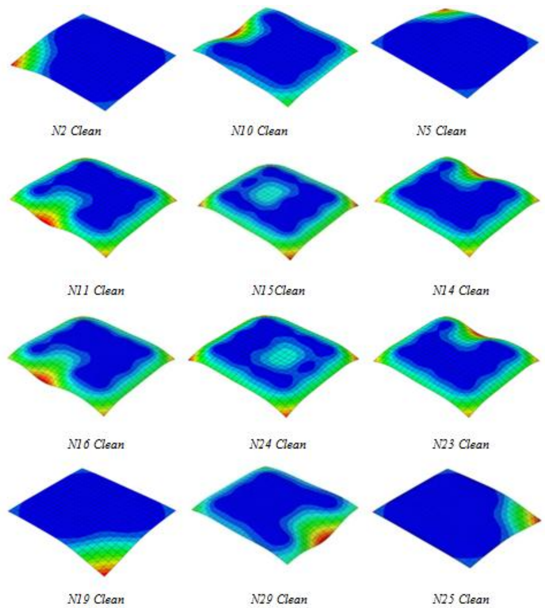

Fig.5
Initial step of work piece analysis by elimination of every 12 supporting point.

According to achieved result from step 1, it is found that there is a point which is not satisfied $\Omega \leq 0.02mm$ therefore VIKOR method is used to obtain best point in order to eliminate. Three phases of VIKOR i.e. the first, the forth and the last phases are indicated in Tables 2,3 and 4 respectively. At first two points i.e. N_{10} and N_{29} are chosen by VIKOR and that is because of the symmetry of the model. Here N_{10} is eliminated and N_{29} is kept arbitrarily. This procedure is continued until reaching stopping point. At the end of the process 6 points are left. This layout is the most optimal one among 12 given points.
$N_{10}, N_{29}, N_{16}, N_{15}, N_{23}$ and N_{24} are eliminated respectively through the process by VIKOR. Other supporting points i.e. $N_2, N_5, N_{11}, N_{14}, N_{19}$ and N_{25}, as illustrated in Fig. 6, are determined as final supporting points and will be used in fixture design.

Table 2
First phase of VIKOR algorithm.

Name result	N_{19} Clean	N_{25} Clean	N_5 Clean	N_2 Clean	N_{11} Clean	N_{15} Clean	N_{14} Clean	N_{24} Clean	N_{23} Clean
	0	0.015594	0.11325	0.119194	0.502488	0.507434	0.510385	0.621274	0.761527
Weights	0.182594	0.182104	0.025009	0.202219	0.201431	0.087954	0.02845	0.029507	0.060731
Criteria type	+	+	+	+	+	+	+	+	+
	KMP01	KMP02	KMP03	KMP04	KMP05	KMP06	KMP07	KMP08	KMP09
N_2 Clean	8.23E-05	1.15E-05	1.19E-05	1.06E-05	1.10E-05	5.12E-06	5.24E-06	5.09E-06	2.16E-06
N_5 Clean	1.15E-05	8.21E-05	1.19E-05	1.07E-05	1.06E-05	5.13E-06	5.13E-06	5.19E-06	2.12E-06
N_{11} Clean	8.98E-06	1.10E-05	5.21E-06	1.08E-05	1.06E-05	5.24E-06	1.02E-05	5.01E-06	2.44E-06
N_{14} Clean	1.10E-05	8.96E-06	5.18E-06	1.07E-05	1.07E-05	5.24E-06	5.05E-06	1.01E-05	2.44E-06
N_{15} Clean	1.04E-05	1.04E-05	4.73E-06	1.04E-05	1.04E-05	4.73E-06	3.79E-06	3.79E-06	8.00E-06
N_{16} Clean	1.12E-05	1.10E-05	6.12E-06	7.82E-06	1.05E-05	3.86E-06	1.05E-05	4.91E-06	3.25E-06
N_{19} Clean	1.11E-05	1.10E-05	5.90E-06	8.13E-05	1.12E-05	1.14E-05	5.41E-06	5.25E-06	1.45E-06
N_{23} Clean	1.10E-05	1.12E-05	6.13E-06	1.05E-05	7.78E-06	3.82E-06	4.94E-06	1.04E-05	3.28E-06

Table 3
4*th* phase of VIKOR algorithm.

Name result	N_{25} Clean	N_{19} Clean	N_{2} Clean	N_{5} Clean	N_{11} Clean	N_{24} Clean	N_{14} Clean	N_{23} Clean	
	0	0.343684	0.368997	0.451	0.758202	0.788994	0.950165	1	
Weights	0.182594	0.182104	0.025009	0.202219	0.201431	0.087954	0.02845	0.029507	0.060731
Criteria type	+	+	+	+	+	+	+	+	+
Average matrix	KMP01	KMP02	KMP03	KMP04	KMP05	KMP06	KMP07	KMP08	KMP09
N_{2} Clean	0.0158	1.14E-05	9.38E-06	1.11E-05	7.68E-06	4.17E-06	3.59E-05	9.83E-06	9.63E-06
N_{5} Clean	8.09E-06	7.45E-05	9.26E-06	1.05E-05	8.05E-06	3.82E-06	9.34E-06	7.92E-06	8.82E-06
N_{11} Clean	3.94E-06	1.10E-05	1.88E-06	1.05E-05	7.11E-06	3.20E-06	1.36E-05	8.53E-06	1.33E-05
N_{14} Clean	6.32E-06	5.92E-07	-1.30E-06	1.00E-05	8.48E-07	4.18E-07	7.77E-06	4.34E-05	2.12E-05
N_{19} Clean	8.11E-06	1.04E-05	3.86E-06	7.46E-05	8.12E-06	9.25E-06	7.96E-06	9.29E-06	8.79E-06
N_{23} Clean	8.50E-07	1.00E-05	1.07E-06	3.70E-06	3.41E-06	-2.60E-07	6.93E-06	1.02E-05	2.27E-05
N_{24} Clean	4.98E-06	9.40E-06	6.65E-06	9.70E-06	6.00E-06	2.51E-06	6.42E-06	5.71E-06	1.54E-05
N_{25} Clean	7.71E-06	1.10E-05	4.21E-06	1.15E-05	0.000158	9.39E-06	9.90E-06	3.57E-05	9.61E-06
Normal matrix	KMP01	KMP02	KMP03	KMP04	KMP05	KMP06	KMP07	KMP08	KMP09
N_{2} Clean	0.994603	0.144779	0.585168	0.140417	0.048329	0.279558	0.829741	0.163536	0.232272
N_{5} Clean	0.050926	0.946144	0.577682	0.132827	0.050657	0.256094	0.215871	0.13176	0.212736
N_{11} Clean	0.24802	0.128269	0.117283	0.132827	0.044742	0.214529	0.314331	0.141908	0.320792
N_{14} Clean	0.39784	0.007518	-0.0811	0.126502	0.005336	0.028023	0.179585	0.722019	0.511337
N_{19} Clean	0.051052	0.132079	0.240805	0.943707	0.051098	0.620124	0.183976	0.154552	0.212012
N_{23} Clean	0.005351	0.126999	0.066752	0.046806	0.021459	-0.01743	0.16017	0.169691	0.547517
N_{24} Clean	0.031349	0.119379	0.414858	0.122707	0.037757	0.168271	0.148383	0.094994	0.371443
N_{25} Clean	0.048534	0.139699	0.262639	0.145478	0.994269	0.629509	0.228814	0.593919	0.23179
Weighted matrix	KMP01	KMP02	KMP03	KMP04	KMP05	KMP06	KMP07	KMP08	KMP09
N_{2} Clean	0.181609	0.026365	0.014634	0.028395	0.009735	0.024588	0.023607	0.004825	0.014106
N_{5} Clean	0.009299	0.172297	0.014447	0.02686	0.010204	0.022524	0.006142	0.003888	0.01292
N_{11} Clean	0.004529	0.023358	0.002933	0.02686	0.009012	0.018869	0.008943	0.004187	0.019482
N_{14} Clean	0.007264	0.001369	-0.00203	0.025581	0.001075	0.002465	0.005109	0.021305	0.031054
N_{19} Clean	0.009322	0.024052	0.006022	0.190836	0.010293	0.054542	0.005234	0.00456	0.102876

N_{23} Clean	0.000977	0.023127	0.001669	0.009465	0.004322	-0.00153	0.004557	0.005007	0.033251
N_{24} Clean	0.005724	0.21739	0.010375	0.024814	0.007605	0.0148	0.004222	.002803	0.022558
N_{25} Clean	0.008862	0.02544	0.006568	0.029418	0.200277	0.055368	0.00651	0.017525	0.014077
Optimal solution	KMP01	KMP02	KMP03	KMP04	KMP05	KMP06	KMP07	KMP08	KMP09
Positive	0.181609	0.12297	0.014634	0.190836	0.200277	0.055368	0.023607	0.021305	0.033251
Negative	0.000977	0.001369	-0.00203	0.009465	0.001075	-0.00153	0.004222	0.002803	0.012876
Distance measure	Positive	Negative							
N_{2} Clean	0.660184	0.192674							
N_{5} Clean	0714264	0.1922							
N_{11} Clean	0877752	0.193405							
N_{14} Clean	0.884504	0.201431							
N_{19} Clean	0.652808	0.19211							
N_{23} Clean	0.903247	0.202219							
N_{24} Clean	0.87706	0.194827							
N_{25} Clean	0.611433	0.179972							

Table 4
7th and last phase of VIKOR algorithm.

Name result	N_{25} Clean	N_{2} Clean	N_{19} Clean	N_{5} Clean	N_{14} Clean	N_{11} Clean			
	0	0.581731	0.705328	0.762431	0.967982	0.980907			
Weights	0.182594	0.182104	0.025009	0.202219	0.201431	0.087954	0.02845	0.029507	0.060731
Criteria type	+	+	+	+	+	+	+	+	+
Average matrix	KMP01	KMP02	KMP03	KMP04	KMP05	KMP06	KMP07	KMP08	KMP09
N_{2} Clean	0.000433	1.76E-05	0.000178	7.10E-06	3.60E-06	0.01E-05	5.94E-05	2.44E-06	3.35E-05
N_{5} Clean	3.68E-06	0.000127	7.51E-05	5.24E-06	3.48E-06	2.18E-05	1.51E-06	3.44E-06	1.70E-05
N_{11} Clean	9.63E-06	4.39E-06	1.71E-05	1.73E-05	1.67E-06	1.86E-05	1.06E-05	2.91E-06	2.50E-05
N_{14} Clean	1.06E-06	7.11E-06	1.43E-05	4.09E-06	6.25E-06	1.60E-05	2.06E-06	3.81E-05	3.31E-05
N_{19} Clean	3.43E-06	5.32E-06	2.18E-05	0.000127	3.43E-06	7.50E-05	3.59E-06	1.66E-06	1.70E-05
N_{25} Clean	3.48E-06	7.04E-06	2.01E-05	1.83E-05	0.000434	0.000179	2.83E-06	5.92E-05	3.37E-05
Normal matrix	KMP01	KMP02	KMP03	KMP04	KMP05	KMP06	KMP07	KMP08	KMP09
N_{2} Clean	0.99965	0.136658	0.904823	0.054684	0.008293	0.101589	0.980762	0.034558	0.49628
N_{5} Clean	0.008496	0.986114	0.381754	0.040358	0.008017	0.110181	0.024932	0.048721	0.251844
N_{11}	0.022232	0.034087	0.086924	0.133243	0.003847	0.094008	.175018	0.041214	0.370358

Clean									
N_{14} Clean	0.002447	0.055207	0.072691	0.031501	0.014398	0.080867	0.034013	0.539611	0.490354
N_{19} Clean	0.007919	0.041308	0.110815	0.978146	0.007902	0.379063	0.059275	0.023511	0.251844
N_{25} Clean	0.008034	0.054663	0.102174	0.140945	0.999791	0.904696	0.046727	0.838451	0.499243
Weighted matrix	**KMP01**	**KMP02**	**KMP03**	**KMP04**	**KMP05**	**KMP06**	**KMP07**	**KMP08**	**KMP09**
N_{2} Clean	0.18253	0.024886	0.022629	0.011058	0.001671	0.008935	0.027903	0.00102	0.03014
N_{5} Clean	0.001551	0.179575	0.009547	0.008161	0.001615	0.009691	0.000709	0.001438	0.015295
N_{11} Clean	0.00406	0.006207	0.002174	0.026944	0.000775	0.008268	0.004979	0.001216	0.022492
N_{14} Clean	0.000447	0.010053	0.001818	0.00637	0.0029	0.007113	0.000968	0.015922	0.02978
N_{19} Clean	0.001446	0.007522	0.002771	0.1978	0.001592	0.03334	0.001686	0.000694	0.015295
N_{25} Clean	0.001467	0.009954	0.002555	0.028502	0.201389	0.079571	0.001329	0.02474	0.03032
Optimal solution	**KMP01**	**KMP02**	**KMP03**	**KMP04**	**KMP05**	**KMP06**	**KMP07**	**KMP08**	**KMP09**
Positive	0.18253	0.179575	0.022629	0.1978	0.201389	0.079571	0.027903	0.02474	0.03032
Negative	0.000447	0.006207	0.001818	0.00637	0.000775	0.007113	0.000709	0.000694	0.015295
Distance measure	**Positive**	**Negative**							
N_{2} Clean	0.675859	0.200532							
N_{5} Clean	0.800722	0.200588							
N_{11} Clean	0.938611	0.201431							
N_{14} Clean	0.91632	0.202219							
N_{19} Clean	0.760573	0.200611							
N_{25} Clean	0590504	0.181571							

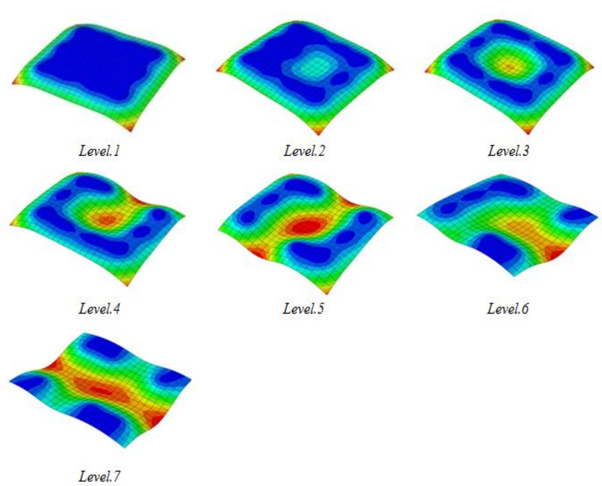

Fig.6
Obtained result from elimination of supporting point in every 7 steps and final layout.

9 CONCLUSIONS

In manufacturing industry, optimal use of equipments in order to hold work piece can enhance quality and reduce construction and maintenance costs of equipment significantly. In this way fixtures have a direct impact on product manufacturing quality, productivity and cost, therefore minimizing work piece deformation due to clamping and welding forces is essential to maintain the machining accuracy. The various methodology used for selecting the optimal location of fixtures such as: linear programming (LP) dynamic programming (DP), goal programming (GP) artificial neural networks and so forth by utilizing Topsis and analytic hierarchy method (AHP) to select appropriate positioning points. In this study, we applied the VIKOR method, which was developed for multi-criteria optimization for finding a compromise priority ranking of selection of the best supporting points in order to eliminate. Proposed model is conducted on an empirical example. In general, in accordance with determined criteria in problem assumptions and fixture design standards the suggested layout would be the best. Consequently the proposed methodology can be successfully applied.

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