About the Institute :

K. K. Wagh Institute of Engineering Education and Research, Nashik is approved by the All India Council of Technical Education (AICTE), New Delhi and Government of Maharashtra, and is affiliated to the Savitribai Phule Pune University. The institute is adjudged as Grade 'A' by Government of Maharashtra. NBA-AICTE, New Delhi has reaccredited five UG Courses. The institute has a picturesque campus of 23 acres, which includes a Polytechnic, Women's Polytechnic, hostels for boys and girls and a well-equipped gymnasium. The institute has developed state-of–the art laboratories for conducting the courses in Computer, E & TC, Electronics, Production, Civil, Mechanical, Chemical Engineering and Information Technology. The intake at undergraduate level is 840 (including 1st & 2nd shift) and 228 at Post Graduate Level. The institute also has Research center in four departments. It is located in Nashik city on the Nashik-Ozhar road at about 4 km from Nashik Central Bus Stand (CBS) and 10 km from Nasik Road Railway station.

About the Department :

Production Engineering Department is one of the pioneering departments, which has produced several rankers at the Pune University Level. The Department is accredited by National Board of Accreditation (NBA), New Delhi. The department has well qualified, devoted and dedicated team of teaching faculty with a blend of experienced and young teachers. The department has started the PG programme in Production Engineering from July 2006. The department is also recognized as Research Center by University of Pune for Ph.D. studies. Five candidates have already completed their Ph.D. from our Department.

About the Conference :

India is emerging as a Manufacturing hub. However, to develop as a global competitive player, a strong techno-managerial strategy is needed for the country to achieve our goal of Make in India. Innovations in Industrial Engineering, Manuafcturing Enginering and Robotics play an important role to achieve this goal. This conference is therefore aimed at providing an interdisciplinary forum for engineering students doing their research/project work in the field of Industrial Engineering, Manufacturing Engineering and Robotics. Participants will also be benefitted through keynote speech by eminent speaker in the field of manufacturing.

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Important dates:

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Confirmation of Acceptance of Paper : 28th March, 2018

Last date for Registration : 29th March, 2018

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Format of paper submission is enclosed.

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2nd AIMTDR State Level Students Conference on Advances in Industrial Engineering, Manufacturing, Tool Design and Robotics

31st March, 2018

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Schedule ❊

Time	Activity
09:00	Registration & Breakfast
09.30	**Inauguration & Keynote Address**
11.00	**Session 1: Industrial Engineering & Tool Design** Papers 1 to 8 **Session 1: Manufacturing Engineering** Papers 1 to 8 **Session 1: Robotics** Papers 1 to 8
13:00	**Lunch Break**
14.00	**Session 2: Industrial Engineering & Tool Design** Papers 9 to 14 **Session 2: Manufacturing Engineering** Papers 9 to 14 **Session 2: Robotics** Papers 9 to 14
15:30	**Tea Break**
16:00	**Session 3: Industrial Engineering & Tool Design** Papers 15 to 20 **Session 3: Manufacturing Engineering** Papers 15 to 20 **Session 3: Robotics** Papers 15 to 20

2nd AIMTDR State Level Students Conference on Advances in Industrial Engineering, Manufacturing, Tool Design and Robotics
31st March, 2018

Organized by
Production Engineering Students Association
Department of Production Engineering
K. K. Wagh Institute of Engineering Education & Research, Nashik

In association with
Indian Institution of Production Engineers,
(Nasik Local Chapter)

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Paper title: Arial, Bold, 14 pt, centered.

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Author/s affiliation: Arial, 10 pt, centered with name of institution, address, and email ID. Write affiliation of each author on separate line.

Abstract: The abstract should not be more than about 200 words. It should be in italics and make it narrower by 0.5 cm at each side.

Heading 1 (main section): Arial, 10 pt, justified, bold.

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Paper text: Arial, 10 pt, justified, single line spacing. All Margins should be set at 1.25". The length of the whole manuscript is limited to SIX pages.

Figures: Place figure captions below figures. The figures should be numbered consecutively with Arabic numbers. Figure captions should be typed in Arial, 11 pt, centered. Please ensure that all figures are of highest quality.

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Lui Y.M., Wang C.J. (1999) "A modified genetic algorithm based optimization of milling parameters", International Journal of Advanced Manufacturing Technology 15, 796–809.

A study of the impact of tool position on performance of a 2-DoF PKM based machine tool while drilling

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Abstract

This paper presents the impact of tool position upon machining performance of a 2-Degrees of freedom parallel kinematic machine (PKM) tool. The behavior of PKM is anisotropic, so structural deformation and a vibration due to cutting loads affects the quality of machined surfaces, according to tool position in the workspace. The aim of the present study is to find the optimal tool position (workpiece location) where the workpiece is machined to a specific quality level. Drilling operations were carried out at various locations within the workspace. Diametral errors of drilled holes measured at each location were considered to study the performance of PKM. The study shows that the tool position has significant impact upon accuracy in drilling operation.

Keywords: Parallel kinematic machine; drilling; tool position; regression model

1. Introduction

Conventional machine tools are designed with massive structures to meet the requirement of high accuracy and stiffness. This limits the flexibility and dynamic characteristics of the machine tool. To overcome these limitations, parallel kinematic machines (PKM) are being considered for machine tools application by researchers. PKMs have advantages of having smaller moving masses, high rigidity and high stiffness to weight ratio (Merlet, 2006; Weck, 2002). PKMs with fixed length legs and lesser DoF are considered more suitable for machine tool applications as it offers more stiffness and workspace in comparison to PKMs with telescopic legs (Albert, 1998). A 3-PRRR parallel manipulator (Kim & Tsai, 2003) and an Orthoglide (Wenger, Chablat, 2002) are the examples of PKM based machine tools with fixed leg length. Planar two-degrees-of-freedom (DoF) parallel manipulators are also being explored for machine tool applications (Lui et.al, 2005; Stan, 2006).

However, limited research is found on experimental studies of the performance of PKM at various tool positions within the workspace. The authors have developed a prototype of a 2-DoF PKM, to explore its effectiveness for drilling operations. Because of the kinematic structure of the PKM, its stiffness and dynamic characteristics vary according to the position of the tool platform within the workspace (Rao et.al, 2003). The methodology to obtain the workspace of a 2-DoF PKM is presented in this paper. A brief discussion on the design and development of PKM is also presented. In order to study the machining performance of the PKM at various tool positions (workpiece locations) within its workspace, an experimental analysis was carried out. Based on the results obtained, an attempt was made to define a suitable region within the workspace for drilling operations.

2. Description and position analysis of a 2-DoF PKM

The kinematic sketch of a typical two-degree-of-freedom PKM suitable for machine tool application is shown in Fig. 1. It consists of two vertical columns with ball screws along which the two sliders move. Sliders and the tool platform are connected with two identical legs. Each leg consists of a four bar mechanism that enables the tool platform to maintain a constant orientation and imparts the required stiffness and rigidity to the PKM. The ends of the legs are connected to the tool platform and the slider by means of revolute joints. Each slider is actuated by an independent servomotor. Actuation of the sliders provides the desired position to the tool platform in the vertical plane. The legs are fixed length and can be made light and stiff and hence can be used in machine tools (Pritschow, 2000). Moreover, this PKM offers a larger workspace since all the joints are of a single DoF type. Referring to Fig. 1, position analysis using a simple geometric approach can be expressed as

$$(z - \tag{1}$$

$$(z - \tag{2}$$

Solving Eq. (1) & (2), the position of sliders, namely, z_1 & z_2 can be expressed as

$$z_1 = z + \sqrt{L^2 - (x - (R - r))^2} \tag{3}$$

$$z_2 = z + \sqrt{L^2 - (x + (R - r))^2} \tag{4}$$

Where, L is the leg length, R is half the distance between two rails, r is half the length of the tool platform and S is the stroke length. And the tool center point, P = (x, z).

Using above equations inverse kinematics of a 2-DoF PKM that relates the position of the sliders, z_i, and the position of the tool platform, P, can be solved. The given position of the tool platform, P, is said to be achievable if the values of z_i satisfy the following

(5)

3. **Workspace of PKM**

The workspace shape of a 2-DoF PKM is complex, unlike that in the case of a conventional machine tool. The workspace of PKM under study is a two-dimensional space reachable by the constant orientation TCP of the mechanism. For the workspace evaluation, a search or discretization method proposed by (Masory & Wang, 1995) is adopted here. The search proceeds by defining a bounding box covering a maximum possible reachable space of mechanism. A box of 1.1m x 0.8m was defined for the workspace analysis of the PKM, and then slicing the bounding box into a number of layers, with each layer being discretized into grid points. For each of these points, the slider position, Z_i, is solved from inverse kinematics Eq. (3) and (4) and checked for its limits using Eq. (5). The stationary singularity and uncertainty singularities, if any, are excluded from the workspace. Based on this methodology a MATLAB program was developed to obtain the workspace of PKM. Workspace of proposed PKM is shown in Fig. 2.

4. **Development of PKM prototype**

Leg length and distance between rails are the critical parameters that determine the performance characteristics of PKM viz. Stiffness, dexterity and workspace. Thus special attention was given to optimize the dimensions of PKM to maximize the stiffness, dexterity and workspace, as presented by (Darvekar et.al., 2012). Optimized dimensions of PKM include leg length L = 660 mm and half of the distance between two rails R = 400 mm (Fig. 1). The values of other parameters considered while optimization were: stroke length S = 380 mm, radius of tool platform r = 40 mm and cross section of each leg: 40 x 60 mm. A specially designed, PC based controller was used to precisely control the slider positions. A photograph of developed prototype is shown in Fig. 3.

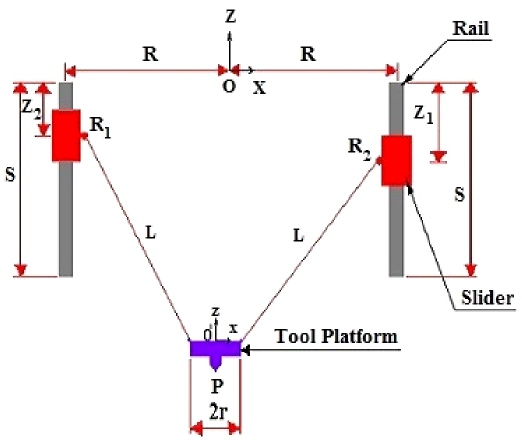

Fig. 1 Kinematic sketch of 2-DoF PKM

Fig. 2 PKM prototype developed

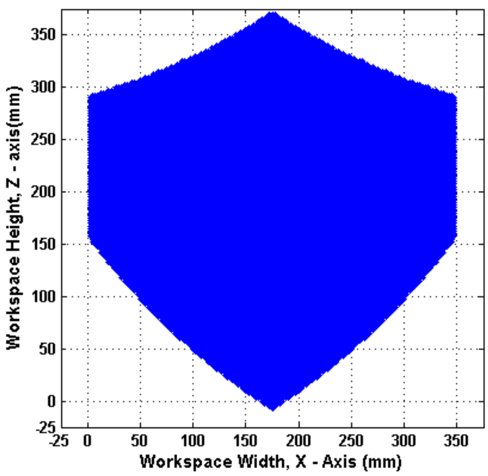

Fig. 3 Workspace of a 2 DoF PKM

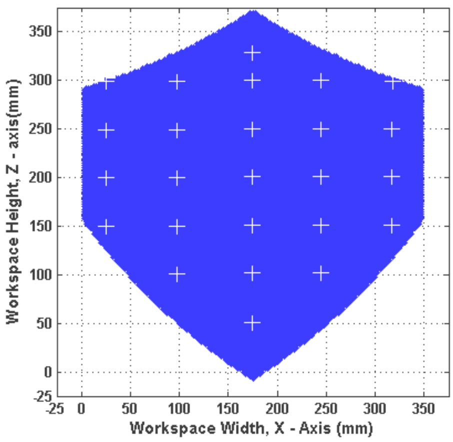

Fig. 4 Tool positions within workspace

5. **Design of Experiment for optimal workpiece location**

5.1. Experimental setup

To study the machining performance of PKM at various locations within the workspace, drilling operations were performed at 25 different locations. Twenty five positions are distributed throughout the workspace as shown in Fig. 4. The workpiece material used in the experiment is Aluminum Al5083 (4.6% Mg, 0.6% Mn, 0.1% Cr, Yield Strength 219 MPa). A standard 2 flute, HSS drill-bit of 6 mm diameter was chosen for drilling operation. The workpiece is a plate of 160 × 80 × 6 mm. Spindle Speed (1000 RPM), feed rate (80 mm/min) was kept constant for drilling holes at all locations (CMTI, 2004). Tool overhang of 75 mm was maintained while drilling holes.

5.2. Measurement procedure

The diametral error of the machined hole is taken as an indicator for analyzing PKM performance at various tool positions. A digital vernier caliper, (Mitutoyo CD-6"CS) was used to measure hole diameter as illustrated in Fig. 5. To minimize measurement errors, the machining was carried out twice at each location with fixed machining parameters, as mentioned before. For each machined hole, nine readings were taken. The average of these (2×9) readings was taken as a final reading. After each cutting process the cutting tool was cleaned and examined. Hole diametral errors obtained while keeping the work piece at different locations are presented in Table 1.

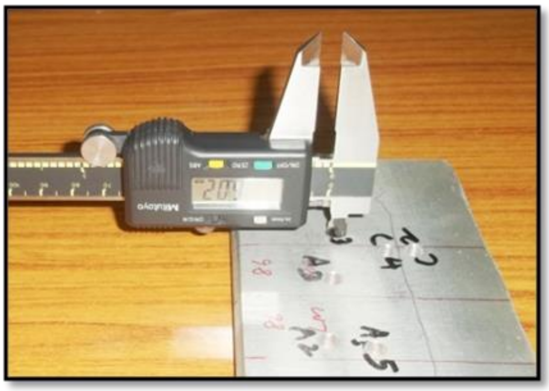

Fig. 5 Hole diametral error measurement

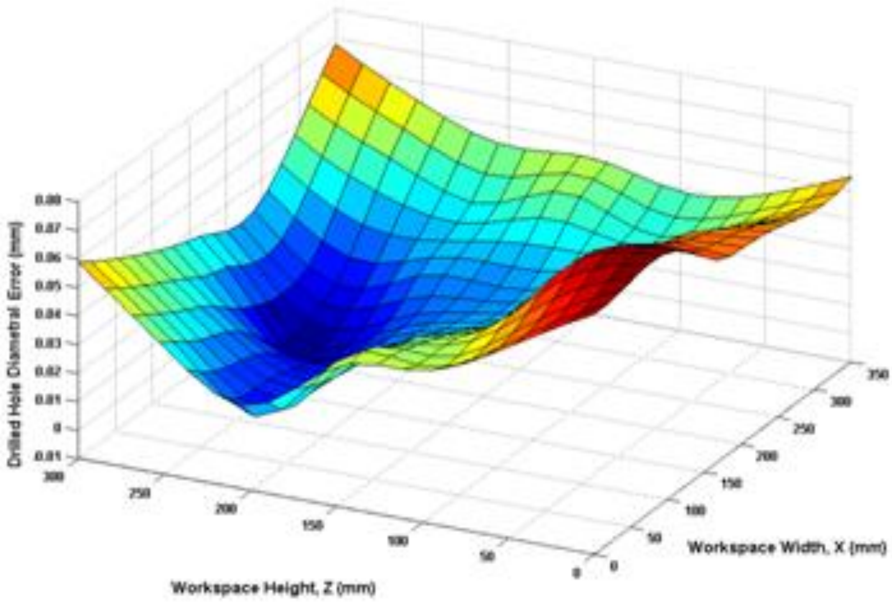

Fig. 6 Errors in hole diameter while drilling at different locations within the workspace

Table 1 Hole Diametral errors at various locations within the workspace

Sr. No	Tool position		Hole diametral error (mm)	Sr. No	Tool position		Hole diametral error (mm)
	Z – axis	X – axis			Z – axis	X – axis	
1	50	170	6.06	14	200	315	6.04
2	100	97.5	6.07	15	250	25	6.01
3	100	170	6.06	16	250	97.5	6.01
4	100	242.5	6.05	17	250	170	6.01
5	150	25	6.04	18	250	242.5	6.02
6	150	97.5	6.04	19	250	315	6.03
7	150	170	6.03	20	300	25	6.03
8	150	242.5	6.03	21	300	97.5	6.02
9	150	315	6.03	22	300	170	6.01
10	200	25	6.04	23	300	242.5	6.01
11	200	97.5	6.03	24	300	315	6.04
12	200	170	6.03	25	325	170	6.02
13	200	242.5	6.02				

6. Results and discussion

From the experimental data shown in Table 1 and from Fig. 6 it can be observed that the diametral error (E_d) is low along the central axis of the workspace (at X=175 mm). As tool deviates from its central axis towards the right or left end of the workspace, diametral error increases. Also, it is noted that diametral error is higher towards the bottom end of the workspace along Z-axis. Variation of diametral error at various locations within the workspace is the result of variation of stiffness and vibration characteristics of PKM, due to its complex kinematic structure. Cutting forces in drilling operation are along the axis of the tool (Z-axis as shown in Fig. 1) (Bhattacharya, 2008). The impact of drilling operation on PKM performance reveals that the stiffness along the Z-axis is relatively high especially when the tool is positioned along the central axis of the workspace. However, since the maximum diametral error value is below 0.04 mm, a 2-DoF PKM can be considered suitable for machine tool application. Entire workspace can be considered suitable for machining operation except a bottom triangular region of the workspace.

7. Conclusions

In this paper a methodology to find the constant-orientation workspace of PKM, based on inverse kinematic equations is presented. Design and development of a 2-DoF PKM for machine tool application is discussed in brief. The performance of PKM at various tool positions in drilling operation is studied. Workpiece location has significant impact upon diametral error in drilling operation. Workspace for specific performance level is determined so that user can choose a suitable location for machining operations. Experimental study shows that the proposed PKM machine tool can successfully perform the machining operation upon metals like high strength aluminum alloy.

Acknowledgement

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