

Design, Fabrication and Tolerance Analysis of Progressive Tool

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ABSTRACT: In the design of a press tool, it is necessary to assign tolerances to all the functional dimensions. The combinations of these tolerances must be sufficiently tight to guarantee that the tool will perform as intended. The performance of the tool can be judged by the dimensional quality of the component blanked out of it. A three stage progressive tool is considered for the analysis. The cumulative effect of the functional dimension tolerances on the assembly dimension tolerance is found analytically using Surefit law and Normal law and numerically using Monte Carlo simulation technique. The goal of this paper is to design and fabricate a three stage progressive tool for producing a sheet metal component and to analyze the tolerances of progressive tool and to find their effect on the accuracy of sheet metal produced out of it. The true positional variation of the pierced holes in the blanked component is also found out experimentally by fabricating the press tool and producing a component and measuring both in Co-ordinate Measuring Machine (CMM). The results obtained using different methods are compared and discussed.

KEYWORDS: True positional error, Progressive tool, Surefit law, Normal law, Monte Carlo simulation technique.

I. INTRODUCTION

Sheet metal working by material shearing mechanisms is one of the most widely used processes in the industry. The quality and accuracy of blanked parts can be characterized according to possible defects, including dimensional, positional, form and surface errors. In a component involving piercing, blanking and bending operations, the positional error of the pierced holes with reference to the blanked contour is decided by the assembly tolerances of the press tool assembly. The assembly tolerances result from the cumulative effect of functional dimension tolerances which form the dimensional loop chain. To analyze the effect of assembly tolerance on the blanked component's dimensional accuracy, a three stage progressive tool for producing the component is considered. A press tool is designed and fabricated for producing a sheet metal component and a tolerance analysis is also conducted on it. The fabricated press tool and the sheet metal component that is produced out of it are inspected using CMM to validate the results obtained analytically.

Md Inaithul Rehman, P Satish Reddy, Matta Manoj, N.Guru Murthy [1] have dealt with the design and analysis of progressive die for chain link plate. The discussion about the types of cutting tools, elements of a progressive tool, shearing theory and action, theoretical calculation of deflection and stress in various parts of the tool were carried out. Vivek D. Barhate, Dr. Sachin G. Mahakalkar, Dr. A. V. Kale [2] have designed a progressive die and discussed about the requirements for the material of die components (die, punch), calculations of forces required for the operations (shear force, stripping force, total force), design of die parts (die block, bottom plate, punch). Mr. Sandeep P V, Mr. C. Vikhresh [3] have reviewed the strip layout design, die plate design, software to design and analyze the progressive tool and assembly of progressive tool design. H. Ameresh, P. Hari Shankar [4] have discussed about the design calculations for the lever component and the structural analysis of the various parts of the press tool. Ch. Mastanamma, K. Prasada Rao, Dr. M. Venkateswara Rao [5] have discussed about the theoretical calculation of the deflection and stress in various parts of the press tool and the structural analysis of the same using an analysis software. The primary outcome of the literature survey is that the knowledge about the design and analysis of the

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progressive tools for producing a typical component is gained. The literature gap which was found in these papers was that experimental validation was not carried out which is being done in this paper.

Paper is organized as follows. Section II describes the design of the various parts of the progressive tool for producing the sheet metal component. The tolerance analysis of the pierced holes in the sheet metal component is carried out analytically and numerically which is explained in Section III. Section IV deals with the fabrication of the progressive tool and validation using CMM.

II. METHODS AND MATERIALS

The work in this paper is divided into three stages. 1) Design 2) Tolerance analysis and 3) Fabrication of press tool. The press tool design is divided into six divisions namely, designs of (a) Die plate (b) Punch plate (c) Piercing punch (d) Blanking punch (e) Top die shoe (f) Bottom die shoe. The tolerance analysis has to be carried out to find the true positional error of the holes analytically and numerically. The fabrication of the press tool is to be done based on the required manufacturing process for the different parts of the press tool. The component which is considered for this research work is made up of aluminium 8011 grade. The top and bottom die shoes are made up of mild steel. The punch plate and stripper plate are made up of EN 8 steel. The die plate and the punches are made up of high carbon high chromium alloy steel.

III. DESIGN OF PROGRESSIVE TOOL

The sheet metal component which is chosen for tolerance analysis is a part of automobile gear box assembly and is shown in fig.1. The true positional tolerance of the holes in the component is given as 0.2 mm based on its application. One of the faces of the slot is taken as the datum plane A and the central axis of the sheet metal component is taken as the datum B.

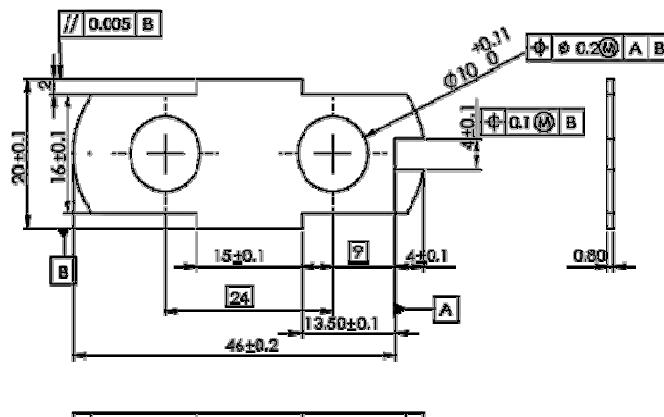


Fig. 1. Sheet metal component chosen for tolerance analysis

The die plate is defined as the block or plate from which the die profile is cut. It is usually the lower member of the tool. It provides the cutting edge. The die plate which is used for producing the chosen sheet metal component is designed and is shown in fig. 2(a). The punch plate holds and supports the different punches in place. The type of fit which is used between the punches and the punch plate is light press fit. The punch plate which is used for producing the chosen sheet metal component is designed and is shown in fig. 2(b). The piercing punch along with the piercing die

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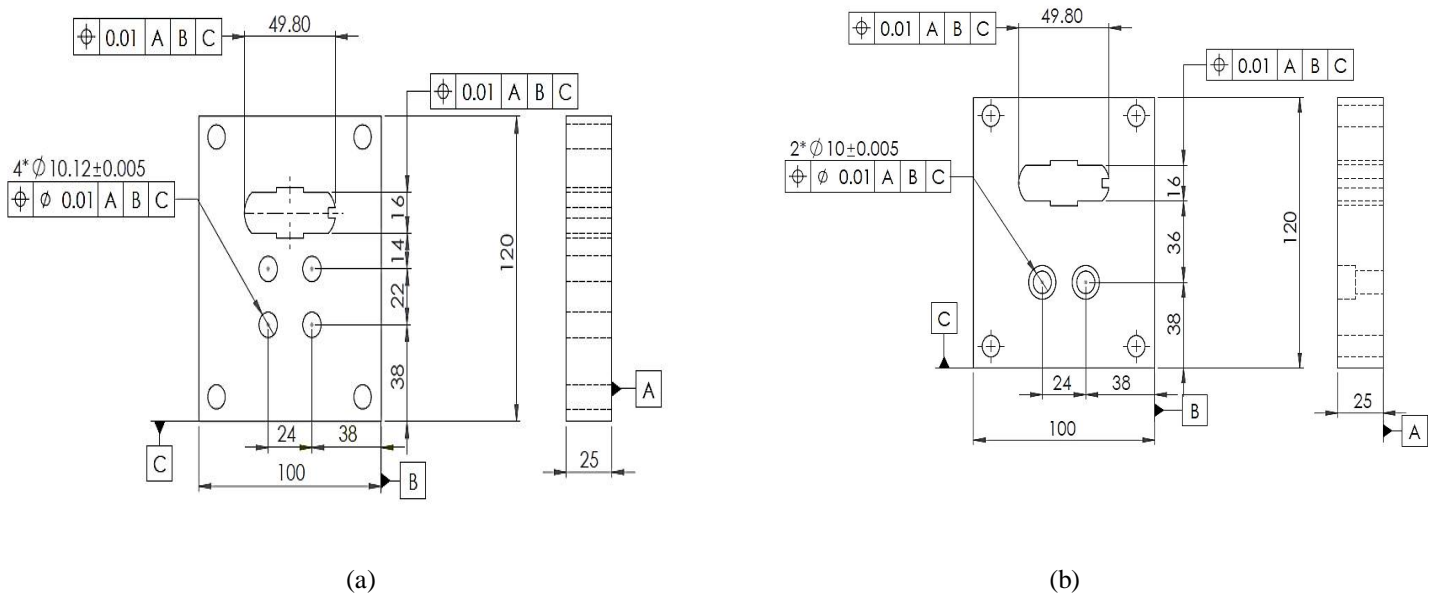
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removes parts from the blanked finished part. The piercing punch which is used for producing the chosen sheet metal component is designed and is shown in fig. 2(c). The blanking punch along with the blanking die produces the blanked part out of the sheet metal. The blanking punch which is used for producing the chosen sheet metal component is designed and is shown in fig. 2(d). The upper working member of the tool is called the top die shoe. The punch assembly including the punch holder and thrust plate is mounted on the top die shoe. The tool shank, which locates the whole tool centrally with the press ram, is also screwed into the top die shoe. The top die shoe which is used for producing the chosen sheet metal component is designed and is shown in fig. 2(e). Bottom die shoe gives cushioning effect to the die as well as provides enough space for the tool to be clamped to the press bed. There may be opening in the base plate, which allows the blank, or slug to fall and clear off from the tool. The die assembly including stripper, all bottom elements are mounted on the bottom die. The bottom die shoe which is used for producing the chosen sheet metal component is designed and is shown in fig. 2(f).

Die clearance is the space between punch and die members. The value of die clearance is usually to be 12% to 18% of the sheet metal thickness. It is taken as 15% for this research work. The thickness of the chosen sheet metal component is 0.8 mm. Therefore, the die clearance is 0.12 mm. Generally it is recommended to use pilots for multi stage operations. Hence, two pilots are used at the second stage to position the pierced holes with reference to the blanked contour of the sheet metal component.



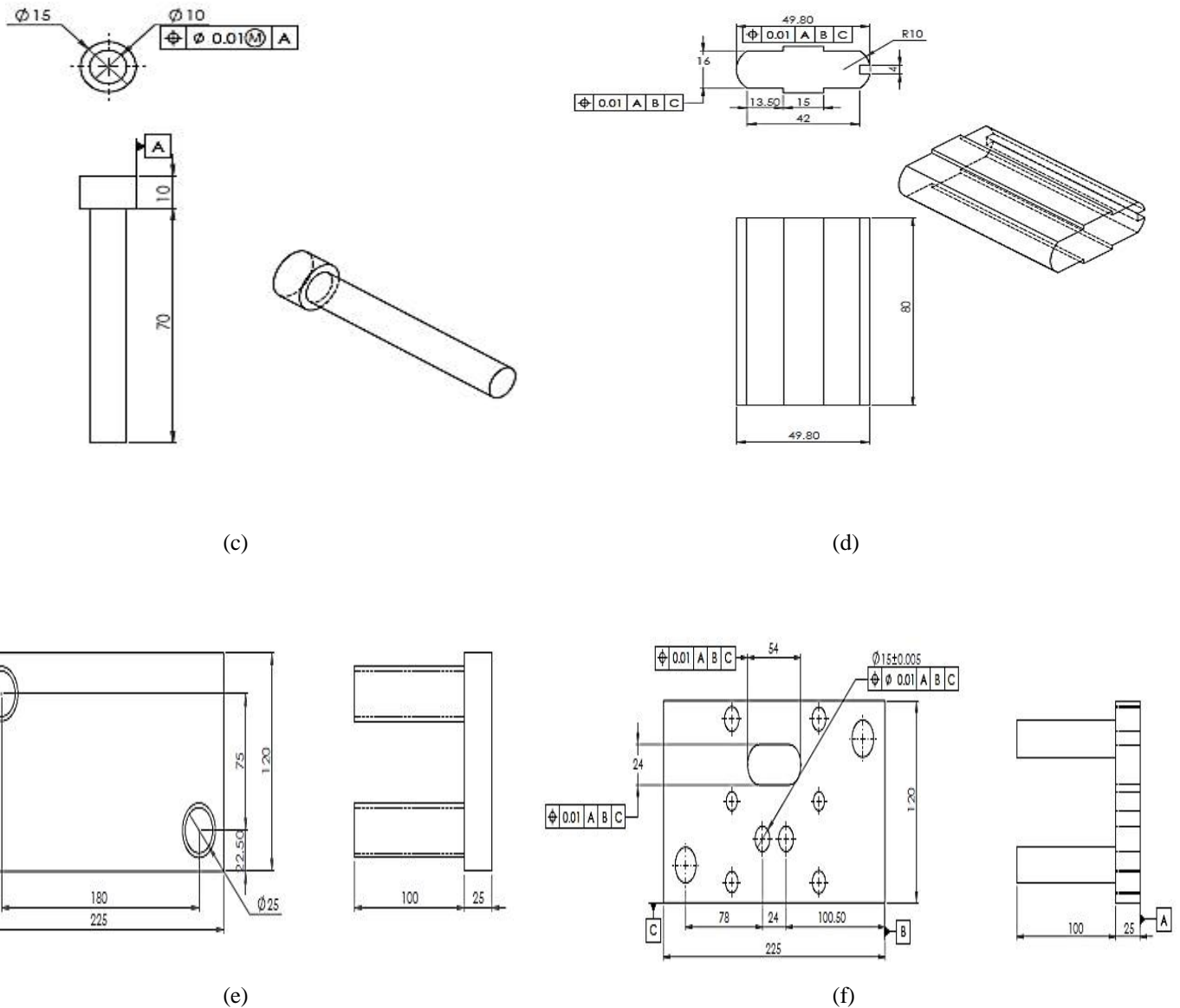


Fig. 2.Design of the parts of the progressive tool (a) Die plate (b) Punch plate (c) Piercing punch (d) Blanking punch (e) Top die shoe (f) Bottom die shoe.

IV. TOLERANCE ANALYSIS

The true positional error of the pierced holes is affected by the piercing and blanking operations. During piercing operation, the cutting edge position of the punch is considered because the size of the punch should be the same as that

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of the hole, whereas in blanking operation, the cutting edge position of the die is considered because the size of the die should be the same as that of the hole. Therefore, true positional error of the hole-1 is calculated using Equation 1[6].

True positional error of the pierced holes in the blanked product = ((Piercing punch cutting edge's position)-(2 * feed step)-(Blanking die cutting edge's position)).....Eqn. 1

The nominal values of the piercing punch cutting edge's position, feed step and blanking die cutting edge's position are shown in fig.3.

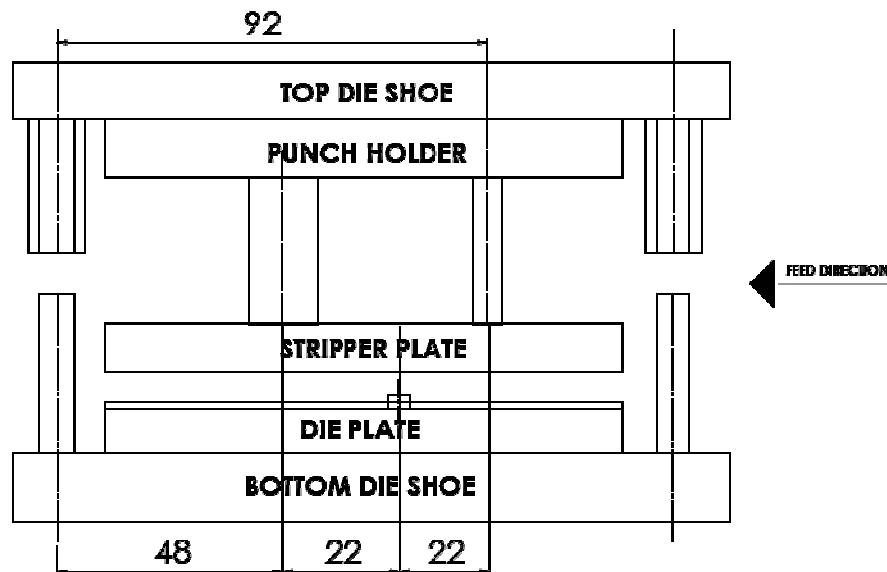


Fig. 3. Arrival of positional error of pierced holes

4.3.1.1 Factors affecting piercing punch cutting edge's position

The various factors which will affect the cutting edge position of the piercing punch are tabulated in table 1.

Table 1. Factors affecting piercing punch cutting edge's position

Feature	Nominal(mm)	Minimum(mm)	Maximum(mm)
Guide post clearance	0.0000	-0.0037	0.0037
Punch plate positioning	10.0000	9.9950	10.0050
Punch plate-position tolerance	82.0000	81.9950	82.0050
Eccentricity of punch	0.0000	-0.0025	0.0025
Parallelism of punch plate	0.0000	-0.0045	0.0045
Parallelism of top die shoe	0.0000	-0.0027	0.0027
Piercing punch cutting edge's position	92.0000	0.0470	

Therefore, it is found that the piercing punch cutting edges are positioned with an error of 0.0470mm.

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Factors affecting blanking die cutting edge's position

The various factors affecting blanking die cutting edge's position are tabulated in table 2.

Table 2. Factors affecting blanking die cutting edge's position

Feature	Nominal(mm)	Minimum(mm)	Maximum(mm)
Die plate positioning	20.0000	19.9950	20.5050
Die plate - position tolerance	86.5000	86.4897	86.5103
Parallelism of bottom die shoe	0.0000	-0.0003	0.0003
Blanking die cutting edge's position	106.5000	0.0206	

Therefore, it is found that the blanking die cutting edge is positioned with an error of 0.0206mm.

True positional error calculation

True positional error of the pierced holes in the component which is denoted in the fig. 1 is calculated using the eqn. 1 and tabulated in table 3.

Table 3. True positional error calculation

Feature	Nominal(mm)	Minimum(mm)	Maximum(mm)
Piercing punch cutting edge's position	92.0000	91.9765	92.0235
Feed step	22.0000	21.9800	22.0200
Blanking die cutting edge's position	48.0000	47.9865	48.0135
True positional error of the hole in the blanked product	0.0000		

The true positional tolerance of the pierced hole in the blanked product is found by the addition of individual feature tolerance according to Surefit law and Normal law.

Surefit law

$$\text{True positional tolerance} = 0.0470 + 0.0800 + 0.0206$$

$$= 0.1476 \text{ mm} < 0.2 \text{ mm (Design tolerance)}$$

Normal law

$$\text{True positional tolerance} = \sqrt{0.0470^2 + 0.0800^2 + 0.0206^2}$$

$$= 0.0948 \text{ mm} < 0.2 \text{ mm (Design tolerance)}$$

So the design is satisfactory.

Monte Carlo simulation software

The Monte Carlo simulation software works on the Excel platform. When the software is initialized, the factors affecting various cutting edge's position are given as input. Now for each factor, the type of distribution is assigned. Normally, the factors are given uniform distribution and the cutting edge's positions are given normal

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distribution. The tolerance value for each of the factor is entered. For the cutting edge's position, forecast is carried out, which is done by clicking the **define forecast** icon and the number of trials which should be carried out is given as 1,00,000. From the output of the software, standard deviation was found to be 0.0300 mm. Therefore the true positional error is 3 times the standard deviation which is equal to 0.0900 mm.

V. EXPERIMENTAL VALIDATION

In order to validate the true positional error of the pierced holes, a press tool was fabricated as shown in fig.4 and the component produced using this tool is shown in fig 5.



Fig. 4. Fabricated press tool



Fig. 5. Produced sheet metal component

The following dimensions were measured using CMM: Piercing punch cutting edge's position in the top die half, Feed step in the bottom die half, Blanking die cutting edge's position in the bottom die half and True positional error of the pierced holes in the fabricated component.

True positional error derived from tool measurements

The true positional error of the two holes of the sheet metal product are first found out by considering the measurements taken on the fabricated tool using CMM.

Blanking die cutting edge's position

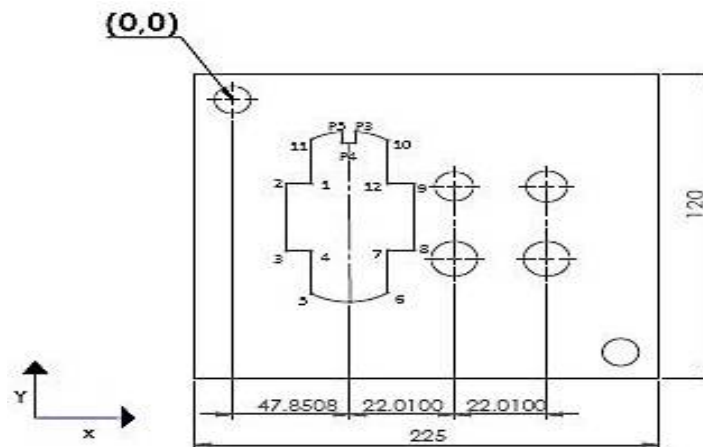


Fig. 6. Blanking die cutting edge's position

Blanking die cutting edge's position is the axis of the outer contour that is machined on the die plate for the blanking operation as shown in fig. 6. The co-ordinates of all the points of the contour are measured using CMM. From this co-ordinates, points 2,9 and 3,8 are used to obtain the blanking die cutting edge's position. The X co-ordinate of point "9" is 57.8891 mm and the X co-ordinate of point "2" is 37.8293 mm. Therefore, the blanking die cutting edge's position is $[(9-2)/2] + X$ co-ordinate of "2" which is $20.0598/2 + 37.8293 = 47.8592$ mm. Similarly, the midpoint of the points "8" and "3" results in the blanking die cutting edge's position of 47.8424 mm. The average of the values of the points 2,9 and 3,8 is calculated and is found as 47.8508 mm which is the blanking die cutting edge's position.

Calculation of true positional error based on tool measurements

True positional error of the pierced holes in the blanked product is calculated using eqn. 1.

$$= 92.1531 - 44.0200 - 47.8508$$

$$= \mathbf{0.2823 \text{ mm}}$$

Therefore, it can be inferred that the component produced using this press tool will have holes with a true positional error of ϕ **0.5646** (2 times 0.2823) mm.

True positional error derived from the component measurements

The true positional error of the holes of the component was measured using CMM. From the CMM measurements, the true positional error of the hole 1 was found to be ϕ 0.0359mm and the true positional error of the hole 2 was found to be ϕ 0.1105mm. The higher value of the true positional error is taken for comparison since it results in the worst case.

VI. CONCLUSION

A sheet metal sample was considered and a press tool was designed and fabricated for the same. Tolerance analysis was conducted on this tool. The press tool and the sheared sample were inspected using CMM. The true positional error of the holes as obtained by different methods is shown in table 4.

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Table 4. True positional error obtained by different methods

METHODS	TRUE POSITIONAL ERROR(mm)
Surefit law	0.1476
Normal law	0.0948
Software	0.0900
Tool measurement	0.5646
Component measurement	0.1105

The true positional error obtained from Surefit law is high because it is a highly pessimistic approach. The Normal law gives a low value of true positional error because it is a highly optimistic approach. The Software result approximately coincides with that obtained from Normal law. It is evident from the experimental analysis that the true positional error of the holes in the component should have been $\phi 0.5646\text{mm}$ as derived from the tool measurements. On the contrary, the true positional error of the holes on the produced sample is found to be $\phi 0.1105\text{mm}$. The reduction of true positional error is effected due to the use of pilots. Therefore it is concluded that the usage of pilots of correct size in a press tool will reduce the true positional error of the holes on the component.

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