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Design of experiment via Taguchi method for machining of aluminium 6061 in shaper machining process

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Abstract

A shaper is a type of machine tool that uses generally cutting in straight direction between the workpiece and a single-point cutting tool. In shaper machine, cutting tool is moved and workpiece is fixed. The shaping machine is used to especially where a large amount of metal has to be removed for producing flat surface. It is also used to cut a internal splines, key way etc. A shaper operates by moving a hardened cutting tool backwards and forwards on the workpiece. In forward stroke, cutting is done and return stroke is idle means no cutting action is done in return stroke. On the return stroke of the cutting tool, Tool is lifted clear of the workpiece.

This paper investigates which shaper input parameters (like feed rate, cutting speed and depth of cut) are affected on surface roughness and high metal removal rate of aluminium 6061 by using of Taguchi method.

1. Introduction

The shaper is a reciprocating machine tool (see fig.1) intended to produce flat surfaces (like horizontal, vertical, or inclined surfaces). Generally, the shaper can produce flat surface by using quick return mechanism. Modern shapers can generate contoured surface. The metal working shaper was developed by James Nasmyth an, Englishman in 1836.

Shaper Operation:

- Cutting Gears/Spines
- Machining irregularity curved surface
- Machining Horizontal/Vertical Surface
- Machining Angular Surface
- Machining V/ Keyway in block

A shaper operates by moving a hardened cutting tool forward and backwards across the workpiece. On the return stroke, Tool is lifted clear of the workpiece, reducing the cutting action to one direction only. By adjusting of ram and mechanism, stroke can be adjusted and stroke length can also be adjusted. It moves faster on the return (non-cutting) stroke than on the forward (cutting stroke). This action is via a slotted link or Whitworth link quick return mechanism.

Fig 1. Photographic view of shaper machine

2. Material and method

Aluminium alloy 6061 is one of the most extensively used of the 6000 series aluminium alloys. It is a mostly heat treatable extruded alloy with medium to high strength capabilities. See composition of Al 6061 in Table 1.

Table 1 Composition of aluminium 6061

Aluminium	*98.8*
Magnesium	*0.8-1.2*
Silicon	*0.4-0.8*
Iron	*Max 0.7*
Copper	*0.15-0.4*
Zinc	*Max 0.25*
Titanium	*Max 0.15*
Manganese	*Max 0.15*
Chromium	*0.04-0.35*
Others	*0.05*

L-9 orthogonal array is using for this experiment. This method is used for three parameter levels such as Cutting Speed, feed of workpiece and depth of cut. Experimental design consists of three types of cutting tool speeds, three types of feed rates and three type of depth of cuts. Taguchi's method of experimentation is best suitable for this study.

This method gives means (average) and variation of experimental results for calculating S/N (Signal to Noise ratio) which describe the test results. From need of specific application, By using these S/N ratio, the range of level can be calculated by design of experiment via Taguchi method. The S/N ratio is considered as smaller is better, larger is better, nominal is best for different output machine response variables. In this study, the value of S/N ratio for surface roughness is considered as smaller is better and metal removal rate is considered as larger is better.. The selection of proper S/N ratio also depends upon the physical properties of the problem.

This analysis is based upon the averages of the experimental result at each level for each parameter. The effect of each parameter (cutting speed, feed rate and depth of cut) can be found by experimentation on each level. In this way, the effect of each parameter is evaluated. From S/N ratio, experimental results evaluate the average response analysis.

In the equations below, y_i is the mean value and si is the variance. y_i is the observed data at i^{th} trial and n is the number of trials.

The S/N ratio for the smaller-the-better is

$$S/_N \quad ratio = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right)$$

The S/N ratio for larger-the-better is:

$$S/_N \quad ratio = -10\log\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right)$$

The working ranges of the parameters (shown in table 2) for subsequent design of experiment, based on Taguchi's L9 Orthogonal Array (OA) design has been selected. In the present experimental study, cutting speed, feed rate and depth of cut have been considered as process variables with their units

Table 2 Input parameters for shaper machining

Cutting Speed (RPM)	32, 44, 68
Feed (mm/rev)	0.15, 0.30, 0.50
Depth of cut (mm)	0.25, 0.50, 0.65

3. Experimental Results and analysis

Taguchi's orthogonal array method is used for S/N ratio calculation of surface roughness (See Table 3) and S/N ratio calculation for MRR (See Table 4). Here requirement of MRR is large so larger is better equation is used for MRR. When smaller-is-better equation is used for surface roughness.

Table 3 S/N ratio value for surface roughness value

Cut Speed (RPM)	Depth of Cut (mm)	Feed Rate (mm/rev)	Surface roughness (µm)	S/N for surface roughness
32	0.25	0.15	2.48	-7.8890
32	0.50	0.30	1.78	-5.0084
32	0.65	0.50	2.70	-8.62728
44	0.25	0.50	3.25	-10.2377
44	0.50	0.15	3.10	-9.82723
44	0.65	0.30	1.40	-2.92256
68	0.25	0.30	2.75	-8.78665
68	0.50	0.50	1.25	-1.9382
68	0.65	0.15	2.25	-7.04365

Table-4 S/N ratio value for MRR

Cut Speed (RPM)	Depth of Cut (mm)	Feed Rate (mm/rev)	MRR Mm^3/min	S/N for MRR
32	0.25	0.15	254.5	57.65618
32	0.50	0.30	900	68.62728
32	0.65	0.50	1555.5	73.37983
44	0.25	0.50	1100	70.37028
44	0.50	0.15	760.5	67.16441
44	0.65	0.30	1790	74.59949
68	0.25	0.30	1180.5	70.98374
68	0.50	0.50	2500	77.50123
68	0.65	0.15	1580.5	73.51832

Now from above calculation, first we decide which parameters are most affected on surface roughness and metal removal rate.

Once these S/N ratio values are calculated for each factors and levels, they are tabulated as shown below table and Range (R) of the S/N for each parameter is calculated and entered into the table(see Table 5).

Table 5 calculation of Range for surface roughness

LEVEL	CUTTING SPEED (N)	DEPTH OF CUT (D)	FEED RATE
1	-7.174893333	-8.971116667	-8.253293333
2	-7.662496667	-5.591276667	-5.572536667
3	-5.922833333	-6.19783	-6.934393333
RANGE (Δ)	1.739663333	3.37984	2.680756667
RANK	1	3	2

So from above rank, cutting speed is most significant parameter for surface roughness and depth of cut is less variation by changing of it.
Now in case of MRR, feed rate is most significant parameter and there is less variation by changing in cutting speed (See below Table 6).

Table 6 calculation of Range for MRR

LEVEL	CUTTING SPEED (N)	DEPTH OF CUT (D)	FEED RATE
1	66.55443	66.33673333	66.11297
2	70.71139333	71.09764	71.40350333
3	74.00109667	73.83254667	73.75044667
RANGE (Δ)	7.446666667	7.495813333	7.637476667
RANK	3	2	1

4. Conclusion

In shaper machine, three parameters are mostly important in case of machining like feed rate, cutting speed and depth of cut. These parameters are responsible for good surface finish and high MRR. Now by experimental analysis on aluminium 6061, feed rate is most important factor for MRR (metal removal rate) and cutting speed is most important factor for high surface finish (low surface roughness).

5. References

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