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Research Article

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Optimization of Drilling Parameters in Aluminium Casting For Minimizing Power Consumption

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Abstract The improvisation of cutting process in manufacturing industry is a continuous changing process through years. The significance of a research work is appreciable when it helps manufacturer and cutting tool designer to understand the nature of machining process and the factors that affect the cutting process. Process parameters during cutting such as feed, spindle speed, drill bit diameter and depth of cut are adopted in various industries on the basis of handbook values, manufacturer recommendation and worker experience. Present work basically involved experimental investigation of thrust force and power consumption by the change in the feed and spindle speed of multi point drilling tool for a drilling operation in the oblique cutting to be carried out with the set of machineries. Thrust force measured using lathe tool Dynamometer. Once the experimental work had been performed, Taguchi's method used to evaluate the best possible combination of input parameters for minimizes. Thrust force and power consumption during drilling operation. The main purpose of this work is save energy during manufacturing of product.

Keywords Drilling Process, Dynamometer, Thrust Force, Power Consumption, Taguchi

Introduction

Machining is a process of removing material from a workpiece in the form of chips, it covers several processes. The term metal cutting is used when the material is metallic. Most machining has very low set-up cost compared to forming, molding and casting processes. However, machining is much more expensive for high volumes. Machining is necessary where tight tolerances on dimensions and finishes are required. The three principal of machining processes are classified as turning, drilling and milling. Other operations falling into miscellaneous categories include shaping, planing, boring, broaching and sawing [1].

Drilling is one of the basic machining process of making holes in a work piece with metal cutting tools and it is essentially for manufacturing industry like aerospace industry, automobile industry, medical industries and semiconductors. It is greatly affected by the cutting parameters like depth of cut, spindle speed, feed rate and cutting edge angle and so on. The present work involves the experimental investigation of thrust force on aluminium casting work piece to find optimum combination of drilling parameter for minimizing power consumption caused by changing the spindle speed and feed of the drill bit for a drilling operation on the lathe machine [2].

Experimental Methodology

Aluminium is the most commonly used material in industries. There are some key characteristics of this material which proves this material is very important for industrial use. Its various properties are its durability, light weight, corrosion resistive, economical and good workability. Hence Aluminium metal is selected as a work piece [3].

High Speed Steel (HSS) is a special type of carbon steel that is prized for the way it can withstand high temperatures while maintaining structural integrity, specifically its well, but only at a level equal to standard carbon steel. HSS can also take coatings, such as titanium nitrate, which give the drill bit better lubricity, decreasing friction and helping to extend the bit's life hardness. Friction created by high speed turning can raise temperatures dramatically, but HSS can undergo these types of drillings. HSS can function at normal temperatures. Hence HSS is selected as a tool material [4].

Table 1: Materials Properties

S. No.	Object	Material	Density	Elasticity
1.	Work piece	Aluminium	2.70 g/cm^3	70 Gpa
2.	Drilling Tool	High speed steel	7.9 g/cm^3	207 GPa

Experimental Setup

Experimental set up having drill bit of high speed steel was mounted on 3-jaw chuck of lathe machine and work-piece was mounted on work-piece holder which was fixed in lathe tool holder and this tool holder fixed at tool post of lathe machine. As shown in the line diagram. Work-piece is fixed at tool post and tool post of lathe machine can move left and right. So work-piece was moving towards the drill bit. Drill bit is fixed at chuck of the lathe machine. Spindle speed of drill bit and feed on work-piece was managed by lever mounted on head stock of lathe machine. Two wattmeter was connected with 3-phase motor of lathe machine which have given power consumption during drilling [5].

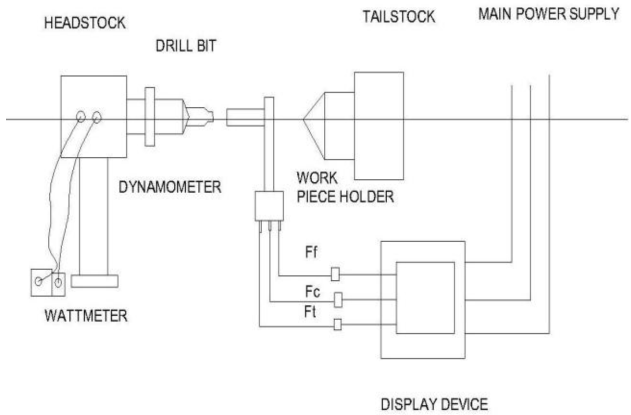

Figure 1: Line Diagram of Experimental Setup

A randomized schedule of runs have been created for all the possible sets of parameter levels being used in the experiment for a number of samples of work piece having same material. Spindle speed and feed were the independent parameters and thrust force and power consumption were dependent parameters. Conducting the experiment each independent variable have certain fixed levels as shown in Table 1 and it have 16 results in total of (4×4) 16 runs (i.e. full factorial design) to be conducted to test all the possible combinations of parameter levels.

MiniTab17 software has been used for processed all the possible run for full factorial design as specified in Table 2 which results in total of 16 runs. Full design approach has included each and every combination of possible experimental run [6].

Table 2: Experimental Levels of Drilling Parameter

Drilling parameter	No. of Levels	Values for each level			
		Level 1	**Level 2**	**Level 3**	**Level 4**
Spindle speed (rpm)	4	150	250	420	710
Feed (mm/rev)	4	0.05	0.07	0.10	0.13

Results and Discussion

To determine the effect of each parameter on the output variable, the signal-to-noise (S/N) ratio was calculated for each experiment by using Taguchi method in Minitab 17 statistical software and result of total 16 (4x4) runs were given in Table 3.

Mean value of experimental data was also calculated for accurate value of power consumption during the drilling operation on lathe machine. After collection of experimental data, to show the effect of each input parameter namely feed (F) and spindle speed (SS) on power consumption (Pc), various plots are generated on the basis of collected data.

Table 3: Power Consumption for Independent Parameters (Constant feed)

Independent Parameters		**Dependent Parameters**		
Feed (mm/rev)	**Spindle Speed (rpm)**	**Power Consumption (Kw)**	**S/N Ratio**	**Mean**
0.05	150	2.08	-6.36127	2.08
	250	1.92	-5.66602	1.92
	420	1.83	-5.24902	1.83
	710	1.75	-4.86076	1.75
0.07	150	2.26	-7.08217	2.26
	250	2.12	-6.52672	2.12
	420	1.98	-5.93330	1.98
	710	1.86	-5.39026	1.86
0.10	150	2.54	-8.09667	2.54
	250	2.32	-7.30976	2.32
	420	2.23	-6.96610	2.23
	710	2.18	-6.76913	2.18
0.13	150	2.74	-8.75501	2.74
	250	2.45	-7.78332	2.45
	420	2.37	-7.49497	2.37
	710	2.28	-7.15870	2.28

Form figure 2, it is clear that for each feed (mm/rev) value when spindle speed is increasing power consumption is reducing. So for minimum power consumption feed should be minimum and spindle speed should be maximum.

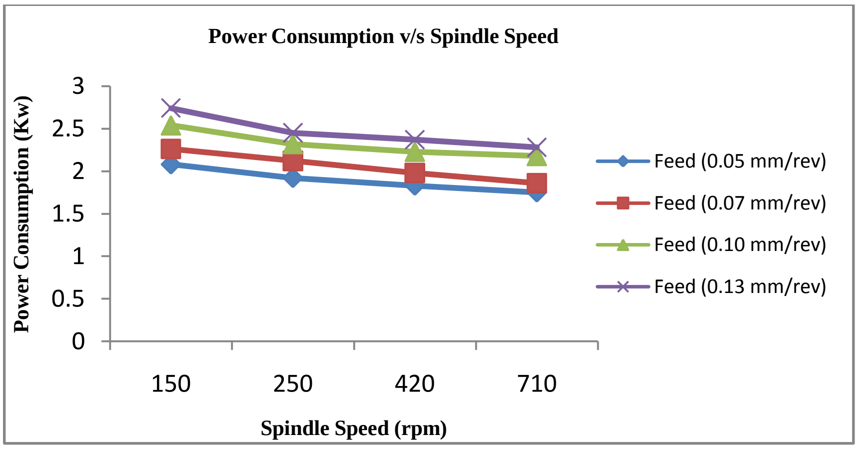

Figure 2: Power Consumption v/s Spindle Speed

So from above graphs it is clear at minimum feed 0.05 mm/rev and maximum spindle speed 710 rpm power consumption is minimum.

Taguchi Method for Power Consumption

Taguchi's methods of experimental design provide a simple, efficient, and systematic approach for the optimization of experimental designs for performance quality and cost. The main purpose of Taguchi method is reducing the variation in a process through robust design of experiments. It was developed by Dr. Genichi Taguchi of Japan. He developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied; it allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources. Analysis of variance on the collected data from the Taguchi design of experiments can be used to select new parameter values to optimize the performance characteristic [7].

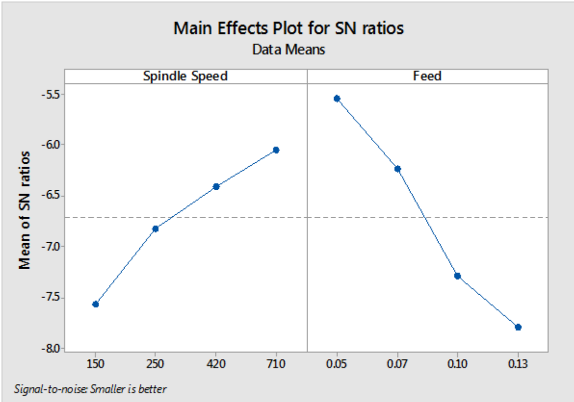

Figure 3: Main Effects Plot for S/N Ratio for Power Consumption

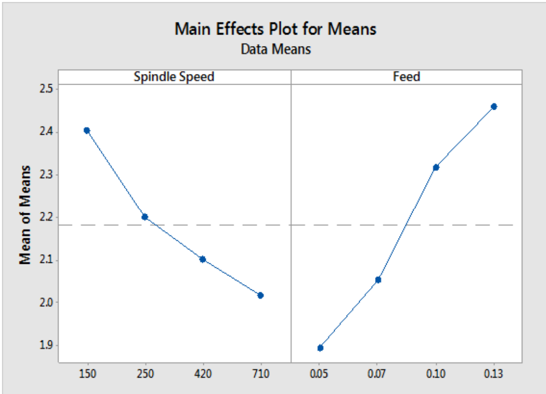

Figure 4: Main Effects Plot for Means for Power Consumption

For this experimental analysis 'The Smaller is better' was chosen to reach the optimization conditions for minimization of power consumption which is the desired condition for drilled machined parts. Main effects plot for S/N ratio and for Means of power consumption was generated by using MiniTab-17 statistical software as shown in Figure 3 and 4 respectively.

Optimized value of power consumption can be analyzed from the main effect plots for S/N Ratio and main effect plot for mean that in order to obtain. In Figure 3 an plot for increasing spindle speed with respect to S/N ratio and Mean is increasing way and plot for increasing feed with respect to S/N ratio and Mean is also in increasing manner. According to plots the feed and spindle speed to their lowest and highest values respectively i.e. 0.05 mm/rev and 710 rpm respectively for achieving minimum power consumption [8].

Response tables for S/N ratio and for Means for power consumption generated in the worksheet of Minitab 17 statistical software are shown in Table 4 and Table 5 respectively. Response tables show rank value of independent parameters.

Table 4: Response Table for S/N Ratios for Power Consumption

Level	Spindle speed (rpm)	Feed (mm/rev)
1	-7.574	-5.534
2	-6.821	-6.233
3	-6.411	-7.285
4	-6.045	-7.798
Delta	1.529	2.264
Rank	2	1

Table 5: Response Table for Means for Power Consumption

Level	Spindle speed (rpm)	Feed (mm/rev)
1	2.405	1.895
2	2.202	2.055
3	2.103	2.317
4	2.018	2.460
Delta	0.388	0.565
Rank	2	1

Response table shows mean value of power consumption at different level of independent parameters which are graphically shown in Figure 3 and Figure 4 respectively. Response tables also show rank value of first and second to feed and spindle speed respectively. Rank value of independent parameters indicates feed is more and spindle speed is less affecting parameter to power consumption.

It is clear from Table 3 that, for a constant feed, but varying the spindle speed shows less variation in power consumption. For example, for constant feed 0.05 mm/rev, varying the spindle speed from 150 rpm to 710 rpm, power consumption decreases from 2.08 Kw to 1.75 Kw.

Conclusion

As per analysis based on graphical method it was found that power consumption during drilling is more influenced by feed, while spindle speed has least effect during the drilling process on lathe machine. From graphical and statistical analysis based on the combination of different input parameters under controlled condition it was found that if implemented in industries will decrease the production cost due to less power consumption.

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