STUDY ON FATIGUE FAILURE OF DIFFERENT DRILL BITS ON 316 STAINLESS STEEL

Arjun PR
Research Assistant
SSIAR Bangalore

Abstract— In metal cutting industries, the fatigue failure is the most important factor that affects the manufacturing process. The quality of the drilled part is greatly influenced by the cutting conditions, tool geometry, tool material, machining process, chip formation, work piece material, tool wear, and vibration during cutting, etc. It is important to appreciate that stainless steel is a solid material and not a special coating applied to ordinary steel to give it "stainless" properties. Conventional steels and, indeed, several other metals, are often coated or "plated" with white metals such as chromium, nickel or zinc to protect their surfaces or to provide other surface characteristics. While such coatings have their own benefits and are still widely used, the danger exists that the coating can be penetrated or damaged in some way; such that it's protective effect is undermined.

The main problem that identified is:

- Overheating of tool and work piece lead to the breakage of the tool.
- Time is the most constrained parameter in an industry while a machining process carrying with respect to the tool life.
- Vibration is the one of the major factor for the tool breakage.
- Shorter life span of tool cost high cost for manufacturing process.

The main objective of the project is to investigate the failure rate of different drill bits while drilling the 316 Stainless steel in upright drilling machine. Obtain the theoretical values of the fatigue failure rate and breakage point by using the Taguchi orthogonal array L27 method. Obtain the failure rate and the specific failure point by using the simulation software ANSYS 17.2 version.

Index Terms— **drilling, fatigue, vibration, ANSYS, stainless steel**

1. INTRODUCTION

The drilling machine is one of the most important machine tools in the workshop. As regards its importance, it is second only to the lathe machine. Although it was primarily designed to make a hole, it can perform a number of operations. By a drilling machine, holes may be drilled quickly and at a low cost. The hole is generated by the rotating edge of a cutting tool known as the drill which exerts large force on the work clamped on the table. As the machine exerts vertical pressure to originate a hole, it is called a "drill press"

Holes may be produced by drilling with twist drill, flat drill, etc., or by boring with one or more single point tools or cutters mounted in a bar or head. Reaming can also be done which is a finishing process. It may be applied to drilled or bored holes to give a better finish. The choice between drilling, boring and reaming depends on several factors, but chiefly on the size of the hole, the accuracy of the hole and the number of holes to be produced. For example, if one or two components are required with an accurately positioned 32 mm hole, they would probably be bored with a single-point tool. But if a large number of such components are involved, they would be drilled and reamed, using a specially designed jig to hold and position the component, having bushes for guiding the drill and reamer to the correct position.

Stainless steel type 316 is part of a family of stainless steel alloys (301, 302, 303, 304, 316, 347). The *316* family is a group of austenitic *stainless* steels with superior corrosion resistance to 304 *stainless* steel. This alloy is suitable for welding because it has a carbon content lower than 301 to 303 series alloys to avoid carbide precipitation in welding applications. The addition of molybdenum and a slightly higher nickel content make 316 Stainless Steel suitable for architectural applications in severe settings, from polluted marine environments to areas with sub-zero temperatures. Equipment in the chemical, food, paper, mining, pharmaceutical and petroleum industries often includes 316 Stainless Steel.

Grade 316 is the standard molybdenum-bearing grade, second in importance to 304 amongst the austenitic stainless steels. The molybdenum gives 316 better overall corrosion resistant properties than Grade 304, particularly higher resistance to pitting and crevice corrosion in chloride environments. Grade 316L, the low carbon version of 316 and is immune from sensitisation (grain boundary carbide precipitation). Thus it is extensively used in heavy gauge welded components (over about 6mm). There is commonly no appreciable price difference between 316 and 316L stainless steel. The austenitic structure also gives these grades excellent toughness, even down to cryogenic temperatures.

Drilling is the primary operation in most of the production processes in the industry. In this operation, it is an important task to select cutting parameters for achieving high cutting performance. The cutting parameters that determine the quality of surface, rate of metal removal and cutting performance are the cutting speed, the feed rate, and the depth of cut.

These cutting conditions and the nature of the material to be cut determine the power required to take the cut. On the other hand these parameters are influential on production cost, machining time and quality of the final product. Improper selection of cutting parameters will lead to severe quality loss and increased cost of manufacturing. So these parameters needed to be optimized to obtain desired surface quality with reduced machining time and cost. So the objective is to find the optimum cutting condition to get desired surface quality.

- Overheating of tool and workpiece lead to the breakage of the tool.
- Time is the most constrained parameter in an industry while a machining process carrying with respect to the tool life.
- Vibrations is the one of the major factor for the tool breakage.
- Shorter life span of tool cost high cost for manufacturing process.

Quality and productivity play significant role in today's manufacturing market. Quality of a product can be described by various quality attributes. The attributes may be quantitative or qualitative. In on-line quality control controller and related equipments are provided with the job under operation and continuously the quality is being monitored. In off-line quality control the method is either to check the quality of few products from a batch or lot or to evaluate the best process environment capable of producing desired quality product

Excellent in a range of atmospheric environments and many corrosive media - generally more resistant than 304. Subject to pitting and crevice corrosion in warm chloride environments, and to stress corrosion cracking above about 60°C. Considered resistant to potable water with up to about 1000mg/L chlorides at ambient temperatures, reducing to about 500mg/L at 60°C.316 is usually regarded as the standard "marine grade stainless steel", but it is not resistant to warm sea water. In many marine environments 316 does exhibit surface corrosion, usually visible as brown staining. This is particularly associated with crevices and rough surface finish.

Good oxidation resistance in intermittent service to 870°C and in continuous service to 925°C. Continuous use of 316 in the 425-860°C range is not recommended if subsequent aqueous corrosion resistance is important. Grade 316L is more resistant to carbide precipitation and can be used in the above temperature range. Grade 316H has higher strength at elevated temperatures and is sometimes used for structural and pressure-containing applications at temperatures above about 500°C.

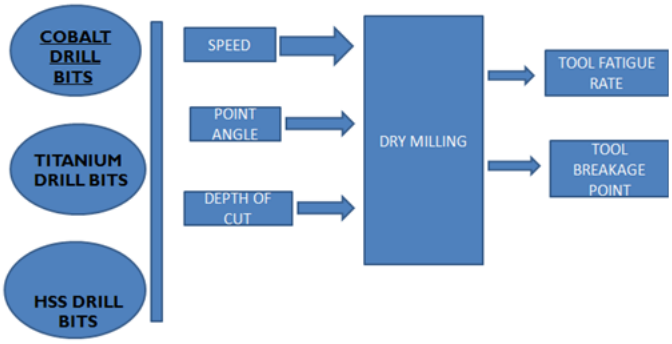
Solution Treatment (Annealing) - Heat to 1010-1120°C and cool rapidly. These grades cannot be hardened by thermal treatment.

Excellent weldability by all standard fusion and resistance methods, both with and without filler metals. Heavy welded sections in Grade 316 require post-weld annealing for maximum corrosion resistance. This is not required for 316L.316L stainless steel is not generally weldable using oxyacetylene welding methods.

316L stainless steel tends to work harden if machined too quickly. For this reason low speeds and constant feed rates are recommended.316L stainless steel is also easier to machine compared to 316 stainless steel due its lower carbon content.

2. METHODOLOGY

PROCESS PARAMETER



BASIC CONCEPT OF TAGUCHI'S TECHNIQUES

Taguchi technique is widely used in the manufacturing application, allow the optimization of parameters in machining by turning, milling, EDM, wire cut EDM, welding, grinding etc to be developed with minimum number of specimens and therefore, least overall cost and time.

Mostly Taguchi's methods are mainly used for experimental purpose. The first quality leader to provide guidance for the product characteristic optimization was Taguchi.When machining any component, it is necessary to satisfy the parameters which governs principally surface roughness, tool wear, temperature, cutting force. The second is the surface metallurgy, which is concerned to the nature of the surface layer produce in machining. A sample of Taguchi's chart of experimentation method is given in the table below. Here the parameters are given and how the readings of each parameter are to be selected is given. These values will give a clear cut idea about the vital few parameters in the hard milling process.

In this project we are considering cutting speed, feed rate and depth of cut. The three parameters are varied in three different levels. This leads us to perform a 27 run experiment using Taguchi's technique. This chart will help us to reduce the number of experiments conducted to find the optimized parameters to prove our research.

The total number of experiments needed to do is only 27, with some set of vibration in parameter as provide in the chart. These charts are filled with output data such as tool wear, surface finish, cutting force and temperature. These are also called response charts. The output responses are plotted in the blank columns and the average responses are find out. These are then plotted into graphs and vital parameters are identified.

The effect column is given to find out the effect of each parameter in this experimentation.

- Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan has developed a method based on "ORTHOGONAL ARRAY" L27 Method experiments which gives much reduced "variance" for the experiment with "optimum settings" of control parameters.

FORMULAS USED

$$\text{Total: } \frac{\Delta\varepsilon}{2} = \frac{\Delta\sigma}{2E} + \frac{1}{2}\left(\frac{\Delta\sigma}{K'}\right)^{1/n'} = \frac{\sigma_f'}{E}(2N_f)^b + \varepsilon_f'(2N_f)^c$$

$$\text{Coffin-Manson: } \frac{\Delta\varepsilon_p}{2} = \varepsilon_f'(2N_f)^c$$

$$\text{Basquin: } \frac{\Delta\varepsilon_e}{2} = \frac{\sigma_f'}{E}(2N_f)^b$$

ANSYS is a general purpose software, used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers.

So ANSYS, which enables to simulate tests or working conditions, enables to test in virtual environment before manufacturing prototypes of products. Furthermore, determining and improving weak points, computing life and foreseeing probable problems are possible by 3D simulations in virtual environment.

ANSYS software with its modular structure as seen in the table below gives an opportunity for taking only needed features. ANSYS can work integrated with other used engineering software on desktop by adding CAD and FEA connection modules.

3. RESULTS AND DISCUSSIONS

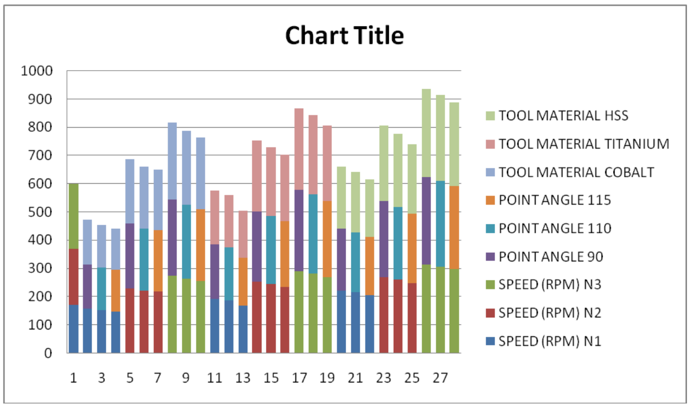
Tool temperature

Response table for Tool temperature

RESPONSE TABLE FOR TOOL TEMPERATURE

Standard order Trail NO.	Respons e Value	SPEED (RPM) N1 170	N2 200	N3 230	POINT ANGLE 90	110	115	TOOL MATERIAL COBALT	TITANIUM	HSS
1	157	157			157			157		
2	151	151				151		151		
3	147	147					147	147		
4	229		229		229			229		
5	220		220			220		220		
6	217		217				217	217		
7	272			272	272			272		
8	263			263		263		263		
9	255			255			255	255		
10	192	192			192				192	
11	187	187				187			187	
12	168	168					168		168	
13	251		251		251				251	
14	243		243			243			243	
15	234		234				234		234	
16	289			289	289				289	
17	281			281		281			281	
18	269			269			269		269	
19	220	220			220					220
20	214	214				214				214
21	205	205					205			205
22	269		269		269					269
23	259		259			259				259
24	247		247				247			247
25	312			312	312					312
26	305			305		305				305
27	296			296			296			296
TOTAL	6352	1641	2169	2542	2191	2123	2038	1911	2114	2327
NO.OF TRAILS	27	9	9	9	9	9	9	9	9	9
AVERAGE	235.26	182.33	241.00	282.44	243.44	235.89	226.44	212.33	234.89	258.56
EFFECT		100.11			17			46.23		

Response Graph for Tool temperature



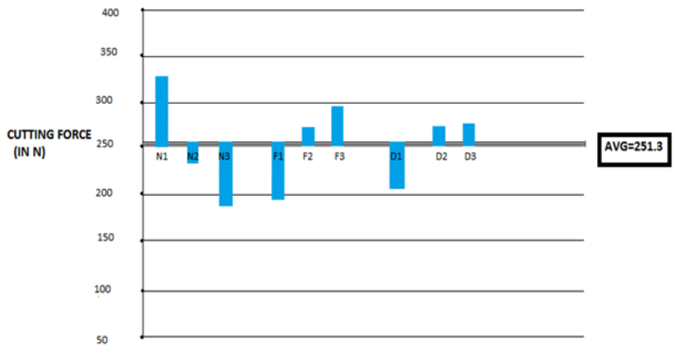
The tool temperature in various trials, the average tool temperature and the effects of cutting speed, feed and depth of cut on tool temperature during drilling are tabulated in the response table, from the table the minimum tool temperature of 147 ºC obtained in trial 3. In trial 3 the spindle speed is 170 rpm, point angle 115^0 and cobalt drilling bit.

The influence of cutting speed, point angle and material of drill on tool temperature during drilling is shown in table. The spindle speed have got more influence on decreasing the tool temperature. The optimum cutting parameters for tool temperature is obtained when spindle speed is 170 rpm, point angle 115^0 and drill material as cobalt.

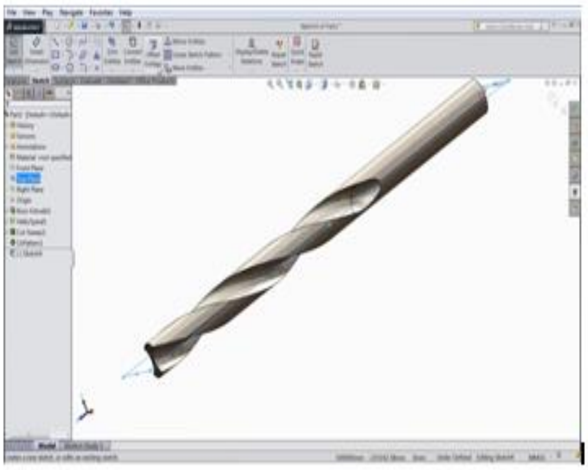
Response table for cutting force

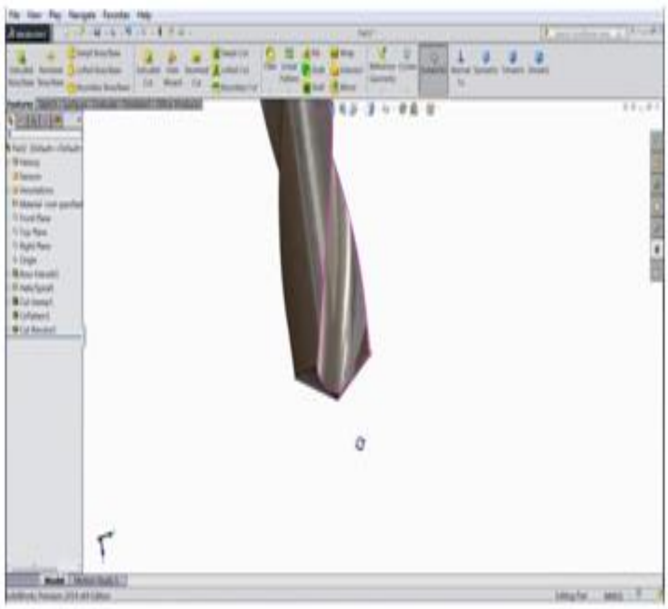
Standard Order Trial No	Response Value	Speed (rpm) N1 170	N2 200	N3 230	POINT ANGLE 90	110	115	Drill material Co	Ti	HSS
1	281.65	281.65			281.65			281.65		
2	179.77	179.77				179.77		179.77		
3	397.15	397.15					397.15	397.15		
4	195.52		195.52		192.52			195.52		
5	240.52		240.52			240.52		240.52		
6	270.30		270.30				270.30	270.30		
7	138.98			138.98	138.98			138.98		
8	121.00			121.00		121.00		121.00		
9	150.41			150.41			150.41	150.41		
10	201.00	201.00			201.00				201.00	
11	555.65	555.65				555.65			555.65	
12	375.76	375.76					375.76		375.76	
13	159.76		159.76		159.76				159.76	
14	243.76		243.76			159.76			243.76	
15	332.98		332.98				159.76		332.98	
16	179.64			179.64	179.64				179.64	
17	132.31			132.31		132.31			132.31	
18	221.43			221.43			221.43		221.43	
19	259.02	259.02			259.02					259.02
20	319.15	319.15				319.15				319.15
21	335.35	335.35					335.35			335.35
22	236.80		236.80		236.80					236.80
23	187.32		187.32			187.32				187.32
24	320.49		320.49				320.49			320.49
25	140.22			140.22	140.22					140.22
26	384.40			384.40		384.40				384.40
27	226.17			226.17			226.17			226.17
Total	6786.6	2902.4	2187.2	1694.4	1792.4	2363.7	2629.5	1975.1	2401.9	2408.7
No Of Values	27	9	9	9	9	9	9	9	9	9
Average	251.3	322.5	243.1	188.3	199.2	262.6	292.2	219.4	266.8	267.6
Effect		134.24			93.01			48.19		

Cutting forcr Vs Input parameters

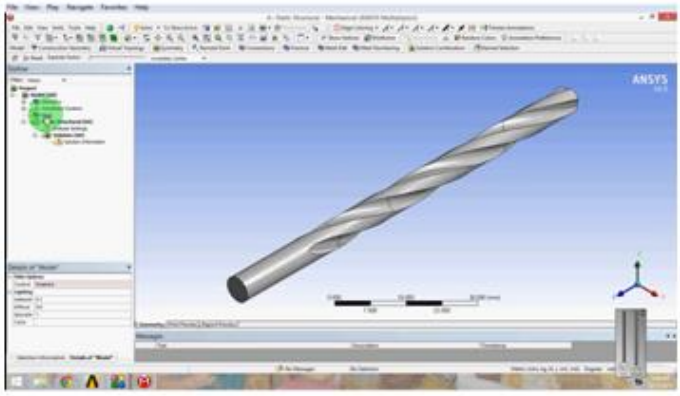


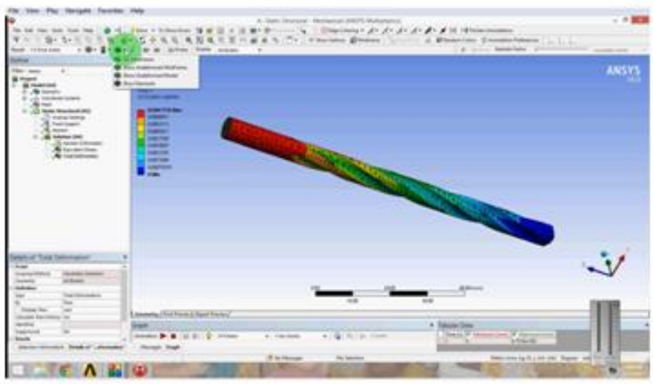
Designing the drill bit using solid work.





Analysis using ANSYS





5. CONCLUSION

Taguchi method is powerful tool for parametric analysis of Tool temperature, fatigue failure rate and breakage point. Comparing the theoretical value with the ANSYS simulation, we can obtain the error value.The main effect of failure can be studied varying different parameters and different drill bits respectively. The prediction of breakage point and life span of drill bits is obtained.

The work is conducted in the Upright drilling machine and the fatigue rate will be obtained for the same and the graphs is plotted.The drilling bit life can be improved by the above data analysis. The drill bit performance can be improved in the future by composite materials usages

6. REFERENCE

1. Diwakar Reddy.V, Krishnaiah.G. et al (2011), ANN Based Prediction of Surface Roughness in Turning,International Conference on Trends in Mechanical and Industrial Engineering (ICTMIE'2011) Bangkok.

1. Mahapatra, S.S. et al (2006). Parametric Analysis and Optimization of Cutting Parameters for Turning Operations based on Taguchi Method, Proceedings of the International Conference on Global Manufacturing and Innovation - July 27-29.
2. Suhail, Adeel H. et al (2010). Optimization of Cutting Parameters Based on Surface Roughness and Assistance of Workpiece Surface Temperature in Turning Process, American J. of Engineering and Applied Sciences 3 (1): 102-108.
3. Van Luttervelt, C. A. et al (1998). Present situation and future trends in modelling of machining operations, CIRP Ann.
4. Kirby, Daniel (2010). Optimizing the Turning Process toward an Ideal Surface Roughness Target
5. Tosun, N., Ozler, L., 2000. A study of tool life in hot machining using artificial neural network and regression analysis. J. mat.proc.Technol. 124, 99-104.
6. Wardancy, T.I.E., Elestawi, M.A., 1997. Prediction of tool failure rate in turning hardened steels. Int.J.manuf,Technol. 13, 1-16.
7. Selvam, M.S., 1975.Tool vibration and its influence on surface roughness in turning. 35, 149–157