ID: 2016-ISFT-162

Experimental Investigation and Analysis of Surface Roughness in Drilling Operation using Response Surface Methodology

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Abstract: *Drilling operation is one of the elementary machining processes of making holes and it is used in manufacturing industry like watch, Aerospace industry, Automobile industry, medical industries and semiconductors. In this study, an attempt has been made to minimize the surface roughness and torque in the drilling process on EN-31 specimens of height (70mm), diameter (40mm) by application of the Response Surface Methodology. Taking into account the drilling speed, feed rate and the drill diameter the machining controlled parameter thrust, torque and surface roughness, are optimized based on the RSM method. A Run order was developed by taking the three factors each having 3 levels using Statistical package. Based on the sequence, drilling was done by taking HSS drill bit of different size diameter. The resultant data are analysed by RSM to find out a combination of optimal drilling conditions. It was observed that high speed, low feed and min diameter gives better results in respect with surface roughness, torque and thrust.*

Keywords: *Surface Roughness; Drilling; Response Surface Methodology (RSM); EN-31;*

1. INTRODUCTION

Drilling is a method to cut holes through a specimen in which various improvements and studies have been carried out over a span of time. Drilling is essentially for manufacturing industry like watch manufacturing industry, Aerospace industry, Automobile industry, semiconductors and medical industries. Drilling is required in industries for assembly related to mechanical fasteners. It was stated that approximately 55000 holes were drilled as a complete single unit in the production of Air bus A350 airplane [1].

The manufacturing industries knowingly have focused their attention on the accuracy in the measurements and surface roughness. This is most important factor and it depicts the quality of the product which is in the consideration. Surface roughness is always tried to be as minimum as possible as then it enhances traits of the material. In the process of obtaining the optimized or most feasible parameters there has been a shift in the ideology now the most preferred characteristic is surface finish.

The requirement to find and chose and induct the optimal conditions is now on the high importance. In the process of developing a surface of the output it is of utmost importance to study and analyze the present scenario of the drilling process. Conventional methods paves the way for high surface roughness and also causes a decrement in the functionality and the usage of the object due to non-optimization of the resources which causes the resources to be wasted and bring no good to the firm. This state also leads to the high investment in the process of drilling or machining and also causes to have high surface roughness. Surface roughness is actually an outcome of the parameters which control the shape and size of the drilling tool. Surface roughness is the factor which is not only hard to measure but also it is very versatile and it depends upon every minute input parameter. So it becomes highly compulsive to have a detailed study of the process to keep the roughness in limits. The parameters on which it depends may be controllable or not.

These parameters are not put in the desired range easily. The cutting parameters which are included in this project work are depth of cut, feed and cutting velocity.

Surface roughness has been one of the most important parameters in the process of drilling as the use of inside surface depends a lot on the finish produced by the drilling process. Surface roughness creates an index of quality which can be used to control the use of the work piece effectively and in a very better way. So, it becomes of high importance to control and understand the nuances of the surface roughness so as to use it in different ways in the industry and home.

2. RESPONSE SURFACE METHODOLOGY

RSM is nothing but an amalgamation of the statistical methods available and their usage in the mathematical manner so that they could be utilized to find out the desired

values which are to be controlled. It is a method which uses apt number of experiments to find out the solutions to the multi variable problems which depend upon the factors [2].

Graphical depictions of these obtained problems are coined as the response surfaces, which are used to designate the individual and combined effect of the input variables on the outputand to find out the relationship these variables share among themselves or between the output also known as response.

Uses of RSM:-

1. To find out the factor level and this will be able to satisfy the desired dimensions.
2. To find the relationship of responses on individual input parameter.
3. To obtain a quantitative knowledge of the system performance in the area
4. To forecast the properties of the product and to find out the responses it would give when the obtained settings are given.
5. To find out the all the necessary situations for the stability of the process.

2.1 TORQUE AND THRUST

Drilling is the most important conventional machining process affiliated to the chipboard processing. In any industry or firm there is high requirement of holes to be produced in the object so as to hold the object or specimen to measure the forces and torque in the body. Very important part which affects this force is the geometry of tool and controls the outcomes. Chip drilling is a drilling process which asks for a very unique set of factors to be set so as to bring the feasible areas in consideration. In this drilling process the parameters or the variables are given importance as they can control the outcome effectively. Any good drilling model is aimed to have precise feed rates, speeds of spindles, and geometries. The analysis of drilling process is known to have complex geometries in it. The complex and intricate geometries of the tool are reason for the varying torque and thrust in the process.

Drill bits are the parts which are used to cut the material and they have a wide variety in their compositions but the shape of such bit tools is mostly cylindrical as the hole to be produced is the basic aim and this can be produced by cylindrical tool only. These bits are made in combination to the static part of the machine which causes the bit to be rotated and produce the desired effect. The bits have two edges.

Exceptionally, specially-shaped bits can cut holes of non-circular cross-section.

2.2 ROUGHNESS

Surface roughness is coined as the deviation or the bifurcation of the surface vector from its real value. If the deviation is more than the surface is rough and if they are small then the surface is smooth. Roughness is the component of surface texture and it consist of the waviness and lay.

3. EXPERIMENT SET-UP

The experimental set up was made by connecting the Radial drilling machine with dynamometer and the results were thus obtained while conducting the experiments.

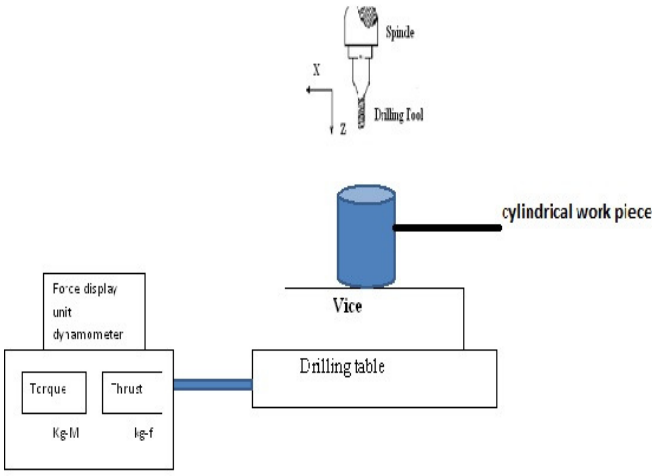

Fig. 1. experimental setup [3]

The material taken in consideration for the study is a relatively new material of EN series. EN-31 is a type of steel which has high quality and high hardness with respect to other type of steels also this is abrasion resistant steel which is superior to the commonly available steels in the market. The compressive strength is also of high degree and better then the available steels bars.

TABLE 1. compositions of EN-31

Carbon	0.90-1.20%	Manganese	0.30-0.75%
Chromium	1.00-1.60%	Sulphur	0.050%at max
Silicon	0.10-0.35%	Phosphorous	0.050% at max

Major applications for EN31 steels include gauges, taps, swaging dies, balls, ejector pins and roller bearings. It is good quality steel demanded for wear resisting machine parts and for press tools which do not require a more complex quality.

Example: Roller Bearings and the ball bearings, spinning tools, Rolls for beadings, Dies and punches also.

A dynamometer is a device used to find the torque and thrust in the machine either in drilling or any other machining process. Dynamometer is nothing but a simple electrical machine which is used to measure the value of the force and torque exactly in the process. A dynamometer is first balanced with respect to a known force and then the

pointer is moved with respect to the new force coming into action at that point or in that process. It is a device for the dynamic calculation of the power produced in the engine while in the common available machine it is used for the prediction of torque.Surface measurement is nothing but the comparison of the previously fixed value with the new value obtained. The taylsurf instrument is used in this experiment is a Taylor Hobson unit with surtonic3+ as its product name. Surtronic 3+ is nothing but an amalgamation of technology so as to achieve high meticulousness and exactitude to have an accurate measurement of surface finish in the process no matter where the work is done, laboratory or the inspection room.

The material thus selected was EN – 31 which is a relatively new material than any other material used as metal for domestic as well as military purposes. The material was then brought in the desired shape so that the force and the torque could be measured during the drilling process. The dimensions required were: Length - 70mm, Diameter – 40mm .

The specimen thus obtained was then drilled and the recorded accordingly on the desired feed speed and the drill diameter. After the drilling process the surface roughness was measured by the tylrsurf surtonic 3+. This gave the measurements of the surface roughness and thereby the roughness was measured. After, this process results were used in the mini tab and thus the graphs and the plots were obtained.

4. DATA ANALYSIS

The design table to be used was made by deciding the values of the parameters to be set in the experiment. Namely, the diameter of drill, feed rate and speed of drill or rpm were set accordingly. The values were defined on basis of the values available in the machine so as to perform the experiment and various levels were selected as shown in table 2.

TABLE 2: levels of the factors of parameters in drilling

Drill diameter(mm)	Feed rate (mm/rev)	Speed (rpm)
8	0.12	150
10	0.2	220
12	0.3	440

The values or the factors were thus defined and with help of Minitab the RSM value table was generated which would set the values or the order of the readings in the experiment. The parameters thus after being defined were made constant for the process and the optimization was thus taken forward.The design was then set and the graphs were obtained between different values depending upon the required values and considerations. The main effects graph is nothing but actually a pictorial representation of the relationship of the input parameters with respect to the other results that are desired. Main effect draws the output variable mean or average value for every level of input set.

TABLE 3: Design Table

Trial	Block	d	f	S		Trial	Block	d	f	S
1	1	0	0	0		11	1	0	0	1
2	1	0	0	0		12	1	0	0	0
3	1	-1	1	-1		13	1	1	0	0
4	1	0	0	-1		14	1	0	1	0
5	1	-1	1	1		15	1	1	-1	-1
6	1	0	0	0		16	1	1	1	-1
7	1	0	-1	0		17	1	1	-1	1
8	1	-1	0	0		18	1	-1	-1	-1
9	1	0	0	0		19	1	-1	-1	1
10	1	0	0	0		20	1	1	1	1

Main Effect Plot: When the line is at 0° to the abscissa then there is relationship present in the variables. Each level of input variable affects the output variable in its own independent way, and output is different in all other input values. When the graph obtained is a line and the line obtained is not at 0° to the abscissa then the value of output depends upon the variable and this causes the objective to draw the graph.

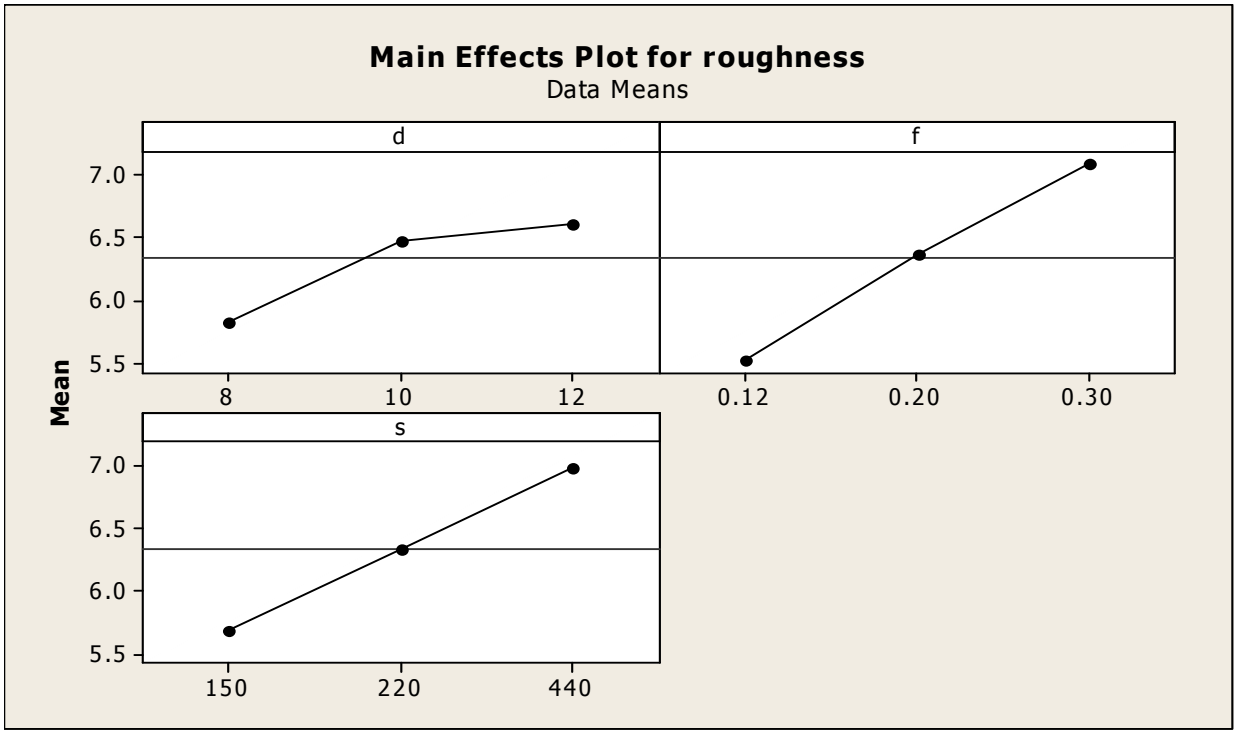

Fig. 2. Main effects plot for roughness [4]

From figure 2 :The main effects plot with d clearly that roughness increases steeply with the diameter increase from 8mm to 10mm, but it increases at a slower rate while increasing from 10mm to 12mm.The change in roughness is nearly constant in the feed and the speed values.

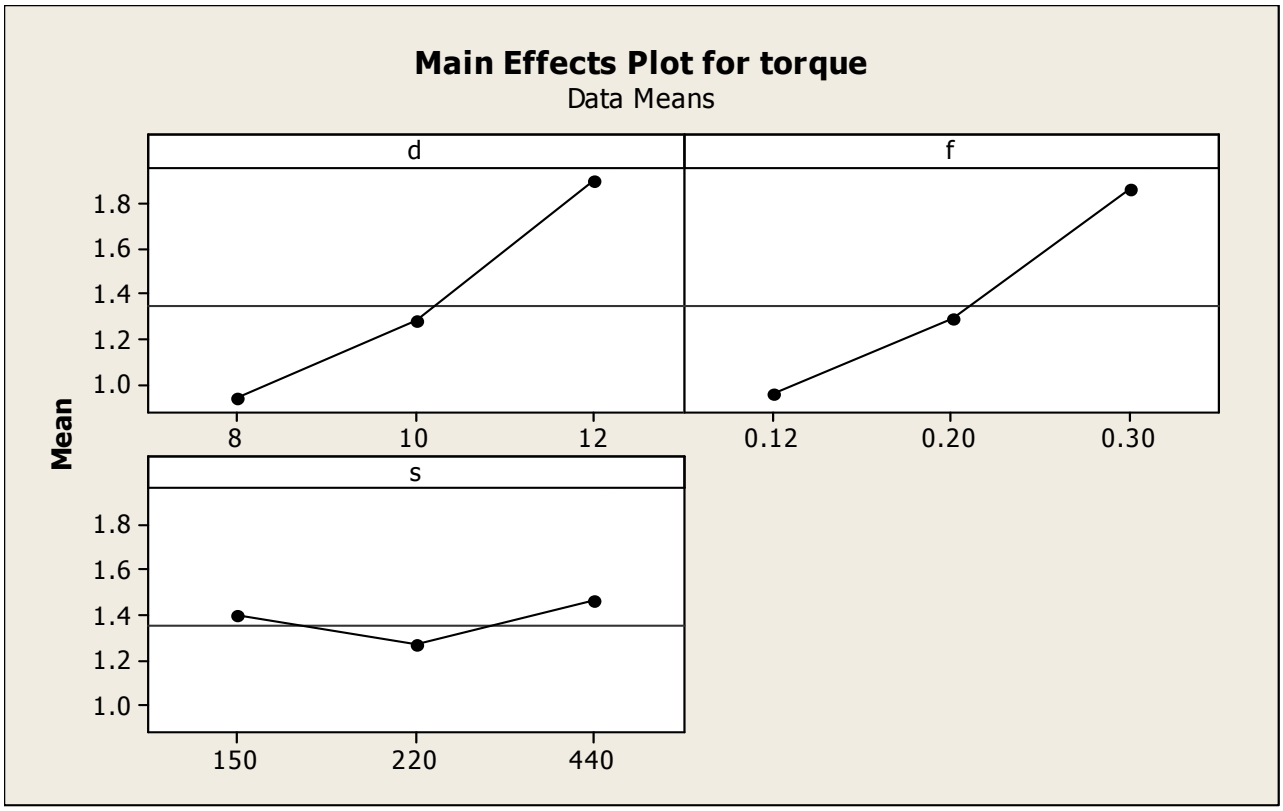

Fig. 3. Main effects plot for torque [5]

From fig. 3. It can be clearly shown that torque varies at a high rate while moving from 10mm to 12mm with respect to the change from 8mm to 12mm.Similar is the effect of f. While, with the s there is only a decrement while moving from 150rpm -220 rpm and again increase while moving from 220rpm -440 rpm [6].

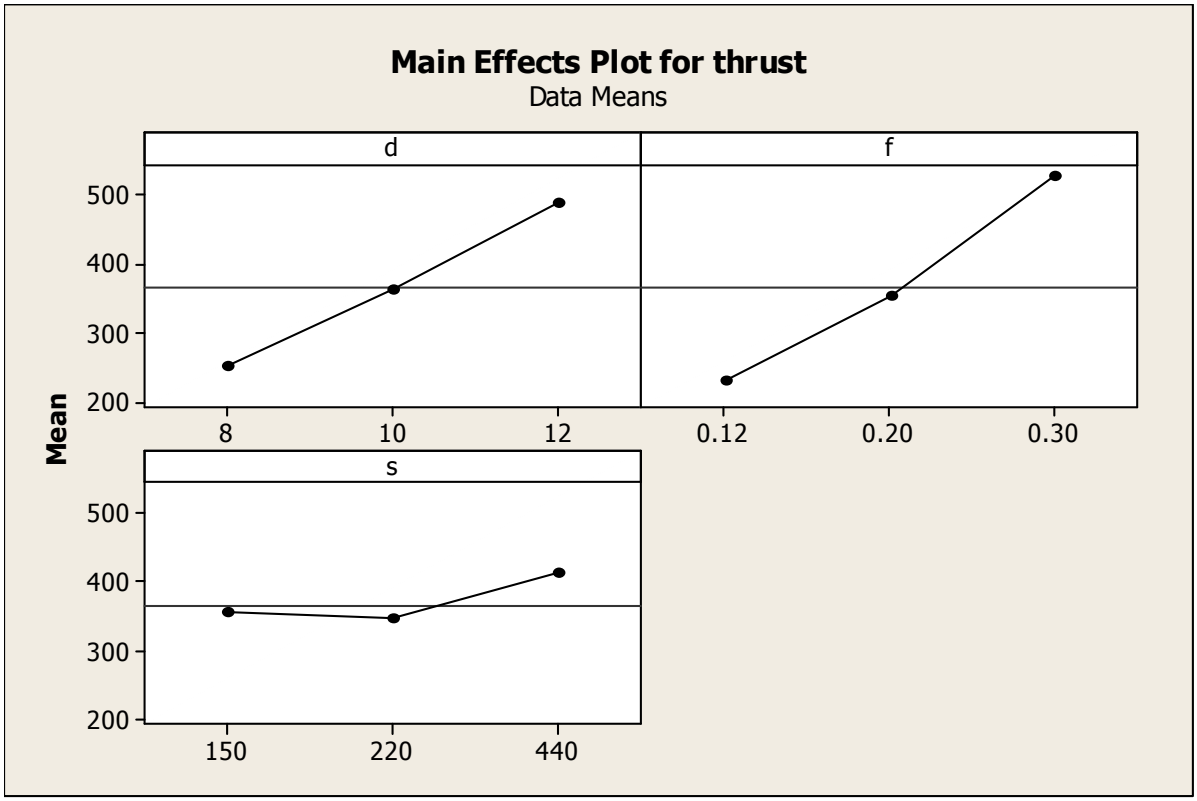

Fig. 4. Main effects plot for thrust [7]

TABLE 4: Target values

	Goal	Lower	Target	Upper	Weight	Importance
Thrust	Target	163.0	500.0	819.0	1	1
Torque	Target	0.5	1.5	2.6	1	1
Roughness	Target	4.3	6.0	9.32	1	1

Mean thrust varies constantly with respect to the d and f

But, with respect to s, the value is nearly same from 150rpm- 200rpm implying that both factors are nearly same in their effect on the mean.

RESPONSE OPTIMIZATION PARAMETERS:

Starting point
Drill dia. = 8 mm
Feed rate = 0.12 mm/rev
Speed = 150 rpm

The optimal plot acts as the reference point for the graph, it can be modified for the settings interactively to obtain different responses. For the factorial and response surface designs, it is possible to adjust the factor levels.

Reasons for changing these input variable settings in the optimization plot are varied but most important are:

1. To find out the input factor value with a higher optimized value
2. To find out cheap input factor settings with near optimized values.
3. To find the ability of response character for the changes in the design variables.
4. To substantiate the predicted outcomes for an input factor setting of desire.
5. To find the input factor start up values in the area near the local solution.

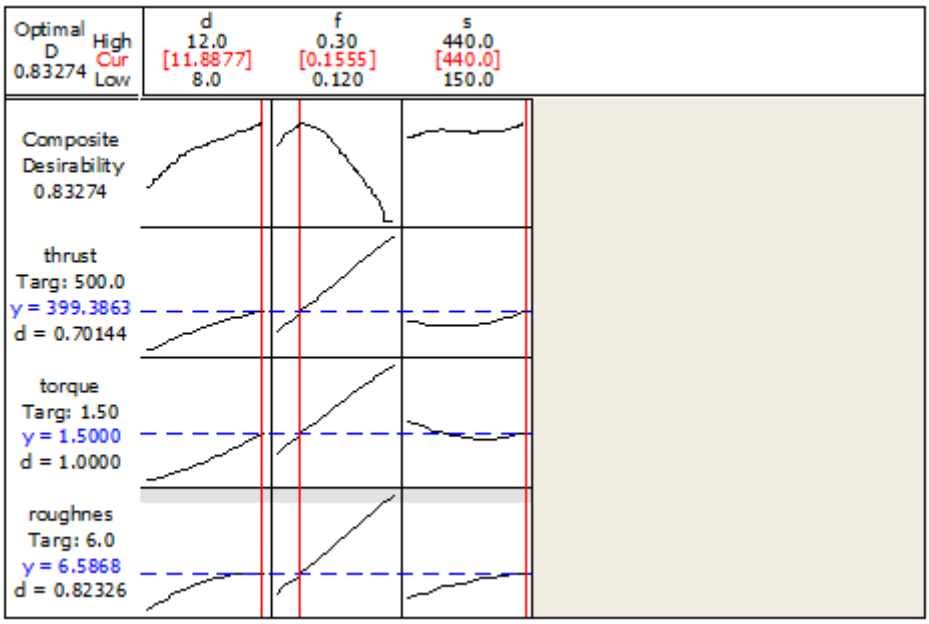

Fig. 5. Optimality plot

Predicted Responses from fig.5
Thrust = 399.386, desirability = 0.701443
Torque = 1.500, desirability = 1.000000
Roughness = 6.587, desirability = 0.823258

Error in thrust from desired value = 500-399.386 = 100.614
Error in torque from desired value = 1.5-1.500 = 0
Error in roughness from desired value = 6-6.587 = .587
Composite Desirability = 0.832740

The optimality plot obtained in the process is aimed to achieve the desired parameters. But due to the approximation involved in the process the values obtained are near to the predictions. At the prediction the setting is: d = 11.8877 mm, f = 0.155478 mm/rev and s= 440.0 rpm

Here, the weights were given to all the responses according to the desired values and with importance or the priority level being set according to the desire the graph was obtained [8].

The values obtained were in control and in accordance to the desired value. So it can be concluded that the RSM method is better method to analyze the process and surface roughness, torque and thrust depends upon the d, s, f and they can be controlled by controlling these factors.

5. CONCLUSIONS

The parameters studied were s,d, f and correspondingly the values were obtained for the thrust and torque in the drilling process. Drill diameter, speed of rotation, feed affect the surface roughness. The torque, thrust and surface roughness are responses of d,s,f and they are controlled by them. With help of the RSM cutting parameters can be obtained for the drilling at the desired cutting responses.

Optimized values for the drilling to have minimum thrust, torque and roughness are:

For roughness to be minimum the parameters to be taken in consideration are:

Drill dia	= 8 mm	Feed rate	= 0.12 mm/rev	Speed	= 150rpm

For torque to be minimum the parameters to taken in consideration are:

Drill dia	= 8mm	Feed rate	= 0.12mm/rev	Speed	= 220rpm

For thrust to be minimum the parameters to be taken in consideration are:

Drill dia	= 8mm	Feed rate	= 0.12mm/rev	Speed	= 220rpm

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