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Simulation of Cutting Parameters Influence on Drill Bit and Surface Temperature in Dry Drilling of S45c Carbon Steel

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Abstract: Drilling process on cutting tool temperature distribution is crucial and important to have a clear and exact data to achieve desirable output. Hole quality tends to have percentage of rejection due to the process using blunt bits. This study analyses the temperature phenomenon by the parameters of cutting speed and feed rate and overall identification of the optimum temperature for the drill bit. Material used for this specific study is S45C for the workpiece and model EZ Drill 0800 and DRS for the drill bits and both of the specimen was designed using SOLIDWORKS software with the conversion of STEP. file to proceed in simulation software of both DEFORM-3D and ANSYS. Observation made that the maximum temperature and highest effective stress value for the EZ Drill 0800 is 149℃ and 1610 MPa respectively. As for the DRS, the maximum temperature and highest effective stress value is 83.5℃ and 1736.2 MPa respectively. It was found that the higher amount of cutting speed and feed rate the higher friction forces applied leading to high temperature value. The right amount of value for the parameter could reduce the chances of breakage and bluntness for the overall drilling process.

Keywords: Drilling Simulation, Carbon Steel S45C, DEFORM-3D, ANSYS, Temperature, Effective Stress

1. Introduction

Machining operations of drilling process are widely used in the industry of engineering field. A standard twist drill bit is used in which cuts a hole through or on a specific depth that equivalent to the diameter of bit. However, occurrence of high temperature on a drill bit and on the surface of material leads to bluntness and therefore cost more on maintenance. The drilling parameters of cutting speed and feed rate are the main factors of temperature occurrence that affects workpiece surface, breakage of bit, bluntness and hole quality in the drilling process. Normally, thermocouples and resistance thermometers are used as for measuring temperature but somehow the calculation analysis the entire amount of value and it's a time consuming for most job. In the last few years, research has been made towards the temperature prediction on the maximum value that occurred in the process of drilling including the design and model created by [1] Hans, Dutt-Brewer model [2]. Loewan-Shaw [3] are made and used for simulation experiment.

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In 1863, Morse, S.A[4] have developed and patent new geometrical drill model to improve the cutting action and increment of chip disposal. By the new model, temperature measurement could be easily calculated due to less chip fragment formation that occurs during the drilling process.

Computer technology has been used as for development in more specific results based on the finite element method (FEM) in simulations of drilling. There are studies was made based on the simulation for drilling process with different accumulation as for the method. Dorr et 2003[5] measure about the temperature that exists during the process of drilling while using different type of coating and the effects that occur based on the value. Bono and Ni [6] have developed a finite element model to predict the heat flow on both of the drill bit and also the workpiece. Jen et al [7] use the numerical analysis method for a specific result of value can be taken or generated with the process of drilling. In this specific study, the effects of cutting speed and feed rate on the temperature were investigated. Drill bit was modelled using the Solid work software as was suggested by Yiannis Kavaratzis [8] on having typical range of 0.5 to 50 mm diameter.

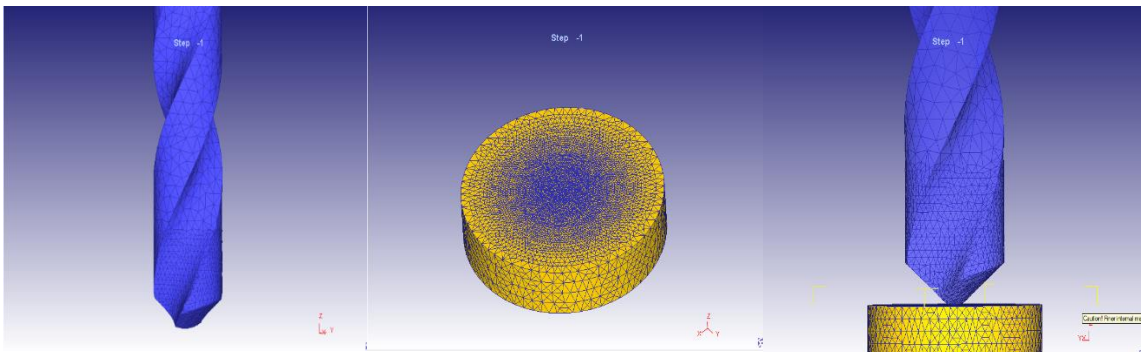
Hence, the objective of this study is to investigate the cutting parameter roles towards bit temperature on material surface of S45C Carbon Steel (1st objective), to identify the optimum temperature on drill bit to lower the risk of bluntness (2nd objective) and to analyse the temperature phenomenon on drill bit and hole surface (3rd objective) using computer aided engineering (CAE) finite element analysis software such as DEFORM 3-D and ANSYS.

2. Materials and Model

Drill bit design and structure was created based on the widely used material which is EZ Drill 0800 and DRS, while the workpiece material is S45C. The specification of model builds according to study done by Wu, J., & Han, R. D. [9] and Yang.S [10]

2.1 Finite Element Modelling

The structure for the drilling model consists of the top die as known as the drill bit and the fixed base of workpiece. Top die was designed using number element sizes of 20,000 with a standardized surface mesh method with the interference depth of the relative by 0.7 to prevent time phase too small errors which could stop simulation suddenly before the necessary duration. The top die was modelled as a fixed rigid body while the workpiece is modelled as plastic structure for deformation to occur on top and in the middle surface of the particular workpiece. Additionally, the top die set as the reference with the interference of 0.0001 for the appropriate connection with the workpiece to have the right position for the process of top die moving downwards following the path of -Z. Figure 2.1 displays the modelled of meshing method for the drill bit and the workpiece while Table 2.1 demonstrates the characteristics of the model to proceed for simulation drilling process.



(a) **(b)** **(c)**

Figure 2.1: Finite Element Modelling for Drill Bit and Workpiece

Table 2.1: Summary comparison of temperature on Dry Drilling based on Drill Bit

Simulation Model	Drill Bit	Workpiece
Diameter (mm)	8	14
Type	Rigid	Plastic
Velocity	Not fixed	Fixed (XYZ)
Initial Temp.	20℃	20℃

2.2 Simulation

The simulation was carried out with cylindrical workpiece made from carbon steel of S45C with thickness of 3.2 mm and diameter of 14 mm. The experiments were carried out with in the range of cutting conditions: feed rate of 0.8, 1.5 and 2.0mm/min with cutting speed from 800 RPM to 900 RPM and the initial temperature for both of the specimen is 20℃. The angle of 118℃ degrees is chosen because it is claimed to be used most in the fabrication department in the field of engineering. Both of the drill bit is tested through different type of software to save time for the observation as well as to learn two different types of dynamic simulation. As well as being a nonlinear method to temperature and stresses problem, the simulation is carried out using ANSYS due to the overall time taken is sorted into a smaller time steps or increments in which n+1 data is collected from the previous time step (n) and does not depend on the current time step [11].

Simulation steps is started by -1 and the accumulative number of steps is 7000. Additionally, the solution step usage for this particular process is the die displacement whereas the increment control is set to constant with the value of 0.0005mm/step. Table 2.2 below shows the entire simulation control based on the overall test for the software.

Table 2.2: Simulation Control

Details	Values
Shear friction factor	0.6
Environment Temperature	20℃
Convection Coefficient	0.02
Heat transfer coefficient	45
Number of Simulation Steps	7000
Tolerances	0.0002
Heat transfer coefficient	45N/sec/mm/C
Element type	Tetrahedral
Mesh type	Fine Mesh
(Drill Bit) Relative mesh type	20000
(Drill Bit) Size ratio	10
(Drill Bit) Material Type	Rigid
(Workpiece) Relative mesh type	21000
(Workpiece) Size ratio	10
(Workpiece) Material type	Plastic
(Workpiece) Shape	Cylinder

2.3 Parameters Equation

The configurations on both of the cutting speed and feed rate are basically the parameters that contributes the friction force that occurred in the process of drilling that results the measurement of temperature (°C) and effective stresses (MPa)

Cutting speed or rotational speed applied on the structural process is equivalent multiplication of the circular constant, drill diameter and the spindle feed per 1000 as was stated in Eq. 1

$$V_c = \frac{\pi DN}{1000} \quad Eq.1$$

Feed rate is defined as the distance travelled during one spindle revolution by the instrument. Relationship of feed rate are equivalent to the multiplication of spindle speed, feed per tooth and the number of flutes based on the drill type and design as shown in Eq. 2

$$Vf = n\ x\ fz\ x\ Z \quad Eq.2$$

3. Results and Discussion

The results and discussion will be split into two parts, which the first part is the result obtained and recorded through the simulation using both of the software of DEFORM 3-D and ANSYS while the second part would be the overall discussion of the data obtained.

3.1 Results

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Table 3.1: Summary comparison of temperature on Dry Drilling based on Drill Bit

No.	Cutting Speed (rpm)	Feed Rate (mm/rev)	Diameter (mm)	(**Drill Bit**) EZ Drill 0800 Temperature (°C)	(**Drill Bit**) DRS Temperature (°C)
1	800	0.8	8	44.1	59.2
2	1600	0.8	8	62.0	74.9
3	800	1.5	8	41.5	80.3
4	1600	1.5	8	70.5	79
5	800	2.0	8	88.0	70
6	1600	2.0	8	149	83

Table 3.2: Summary comparison of temperature on Dry Drilling based on Workpiece

No.	Cutting Speed (rpm)	Feed Rate (mm/rev)	Diameter (mm)	(**Workpiece**) EZ Drill 0800 Temperature (°C)	(**Workpiece**) DRS Temperature (°C)
1	800	0.8	8	149	59.2
2	1600	0.8	8	358	75
3	800	1.5	8	122	80.2
4	1600	1.5	8	265	79
5	800	2.0	8	203	70
6	1600	2.0	8	346	83

Table 3.3: Summary comparison of Effective Stress on Dry Drilling

No.	Cutting Speed (rpm)	Feed Rate (mm/rev)	Diameter (mm)	EZ Drill 0800 Effective Stress (MPa)	DRS Effective Stress (MPa)
1	800	0.8	8	1470	1238.4
2	1600	0.8	8	1530	1292.2
3	800	1.5	8	1560	1250
4	1600	1.5	8	1540	1401
5	800	2.0	8	1610	1517.5
6	1600	2.0	8	1260	1736.2

3.2 Discussion

Based on the result recorded through the simulation of drilling process, Table 1 and Table 2 result were produce using the software of DEFORM 3-D while table 3 was recorded through the result from ANYSY software. The temperature observation has been made that the EZ Drill 0800 highest value is 149℃ as the cutting speed is 1600RPM and the feed rate is 2.0mm/sec, while the DRS drilling process highest temperature is 83.47℃ that has the same speed and feed rate. Therefore, with that being said, material and mechanical properties of drill bit revolve around the atmospheric of drilling process as most of drill bits has its own coating and functionality towards working with workpiece or any other material. To summarize through a graph in Figure 3.1 and Figure 3.2, it is clear that the maximum temperature changes in every aspect of parameters given for the process in dry drilling. The line pattern for the EZ Drill 0800 temperature increasing in both type of cutting speed which makes the maximum of temperature boost significantly passing DRS while DRS pattern create a space whereas the slower

pace of cutting speed alongside with a higher feed rate value raise chances of decreasing the temperature in time.

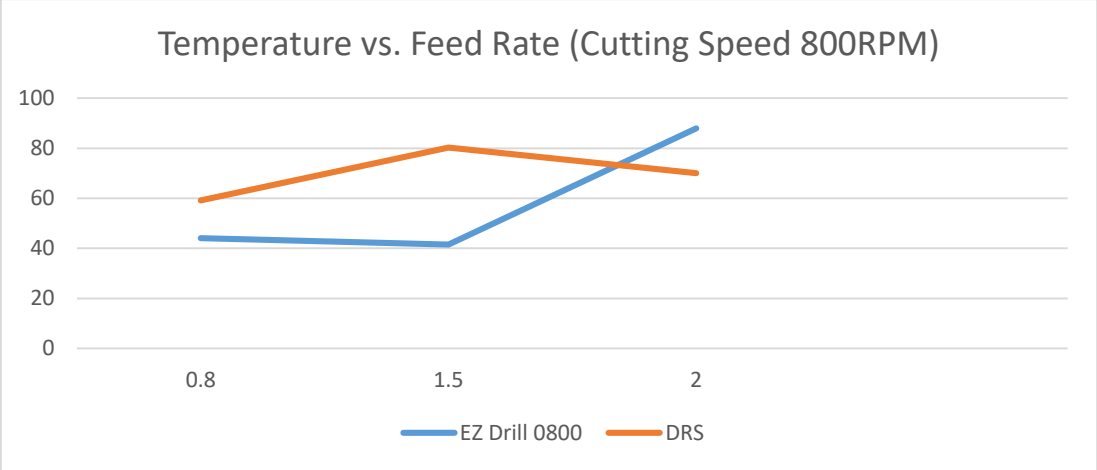

Figure 3.1: Drill Bit temperature vs. Feed rate with cutting speed of 800 RPM

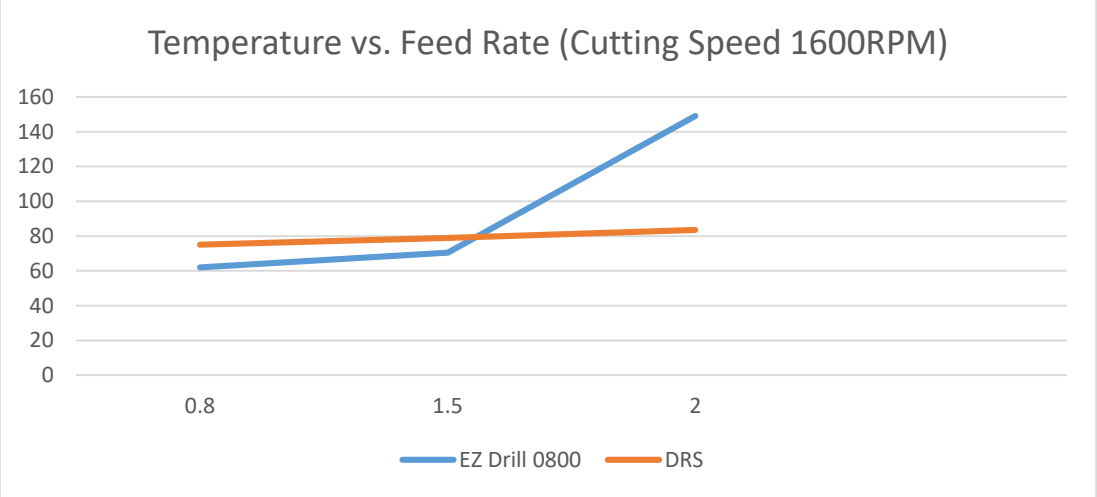

Figure 3.2: Drill Bit temperature vs. Feed rate with cutting speed of 1600 RPM

As for the effective stress result that was obtained in Table 3.3 of simulation process, the highest value that could be found on both of the drill bit is 1736.2 MPa that has been created by DRS drill bit with the cutting speed of 1600 RPM and feed rate of 2.0mm/sec and the lowest is 1238.4 MPa with cutting speed of 800RPM and feed rate of 0.8 mm/sec. Basically, the value for the stresses on both drill bits are all over 1000 MPa in every parameter given. According to the graph stated in Figure 3.3 and Figure 3.4, the graph is basically the summary of the effective stress against the feed rate that has been provided with the cutting rate of 800 RPM and 1600RPM. The graph describes that, on the lower cutting speed, the effective stress tends to increase without dropping any values during the process while on the higher cutting speed, DRS drill bit is rising from time to time based on the feed rate given and the EZ Drill Bit maximum effective stress line bend down as it drops the value as the feed rate getting higher.

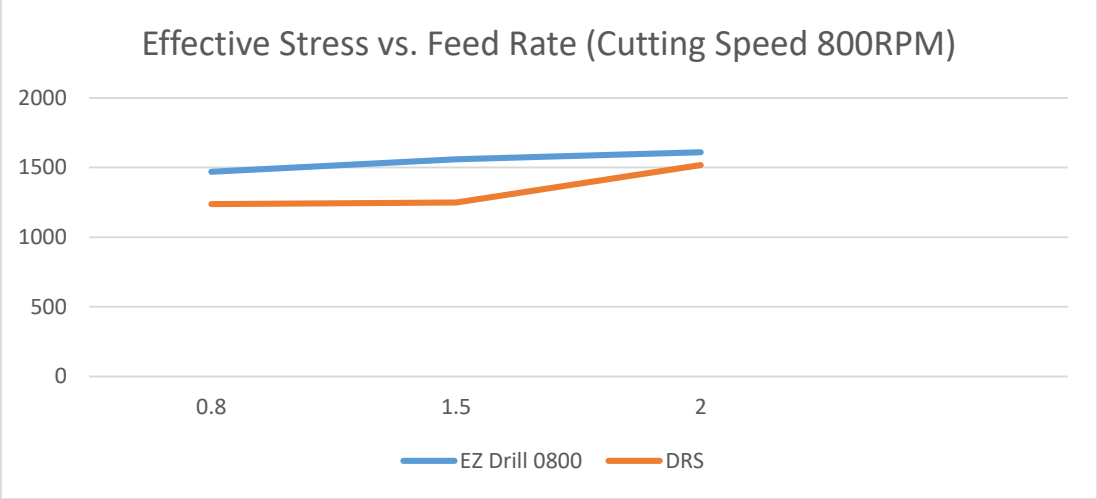

Figure 3.4: Effective Stress vs. Feed rate with cutting speed of 800 RPM

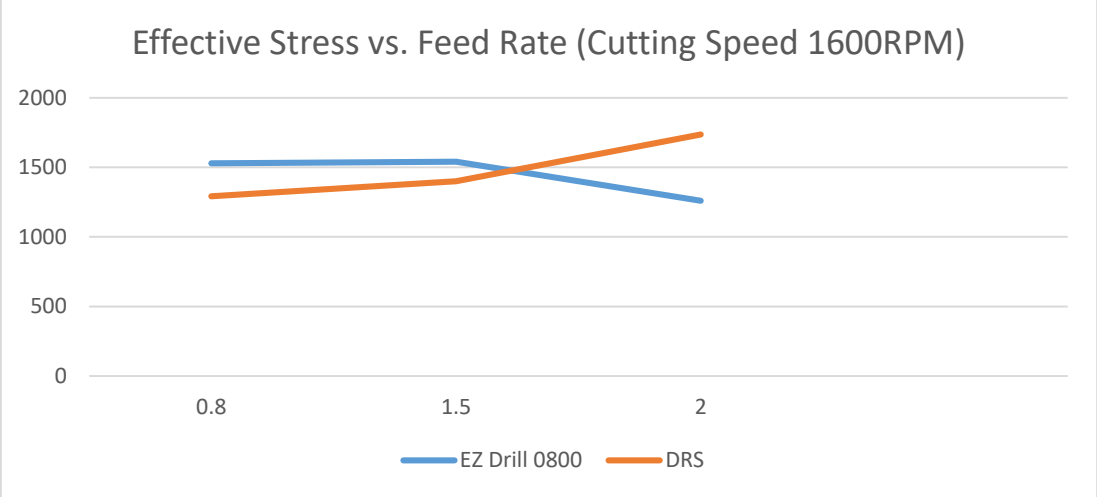

Figure 3.5: Effective Stress vs. Feed rate with cutting speed of 1600 RPM

4. Conclusion

According to the analysis results obtain from the simulation of dry drilling process, objective and aim specified for the project has been achieved by using the Finite element analysis method. Critical study has taken places to understand the influence of the parameter in drilling process alongside in finding the best optimum desirable temperature for a better performance throughout the process. Analytically, the material model has a great effect on the accuracy of finite element models of the drilling temperature. Findings that are obtained from this project are listed below:

- Type od drill bit usage for the drilling process is very important to work with different material of specimen or workpiece
- EZ Drill bit develop higher temperature compare to DRS
- Higher feed rate value alongside with higher value of cutting speed will create a higher amount of excessive temperature, effective stress and also high chances of dullness on the chisel edge of drill bit.

Acknowledgement

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