Numerical Analysis in Friction Drilling Of AISI1020 Steel and AA 6061 T6 Alloy

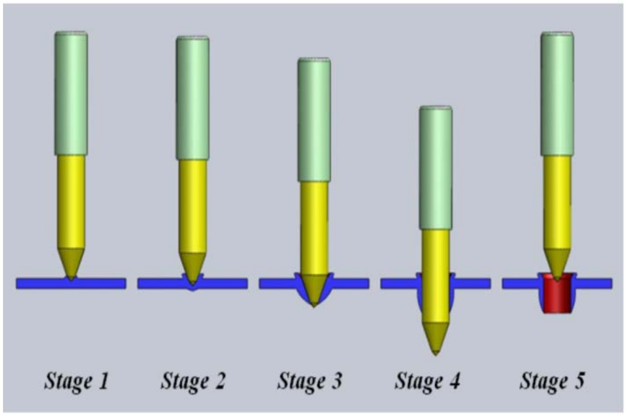
N.Rajesh Jesudoss Hynes, M. Muthu kumaran, N. Rakesh and C.K.Gurubaran

Abstract: Friction Drilling is gaining importance in the last decade due to the demand for making holes in aerospace and automobile applications. In this process, a rotating tool penetrates the work piece and creates a bushing in a single step without generating chips. In the present work, numerical analysis of the process has been carried to study the thermal behavior of the materials. The computed heat flux is applied to the numerical model and temperature distribution is predicted for work materials such as AISI 1020 Steel and AA 6061 T6. The point of contact between tool and work piece experiences maximum temperature during the first few milliseconds. In that heat affected zone the material softens and flows out to become a bushing so that subsequent internal threads could be made.

Keywords: *Friction Drilling, AA6061 T6, AISI 1020, Temperature distribution*

1. Introduction

Friction drilling, also known as thermal drilling, flow drilling, form drilling, or friction stir drilling, is a nontraditional hole-making method. The heat generated from friction between a rotating conical tool and the work piece is used to soften the work material and penetrate a hole. It forms a bushing directly from the sheet metal work piece and is a clean, chip less process.



a) b) c) d) e)

Fig.1. Stages of Friction Drilling.

Fig 1 shows schematic illustrations of the five steps in friction drilling. The tip of the conical tool approaches and contacts the work piece, as shown in Fig. 1a. The tool tip, like the web center in twist drill, indents into the work piece and supports the drill in both the radial and axial directions. The friction force on the contact surface produces heat and softens the work-material. The tool is then extruded into the work piece, as shown in Fig. 1b, pushes the softened work material sideward, and pierces through the work piece, as shown in Fig. 1c. Once the tool tip penetrates the work piece, as shown in Fig. 1d, the tool moves further forward to push aside more work-material and form the bushing using the cylindrical part of the tool. The shoulder of the tool may contact with the work piece to trim or collar the extruded burr on the bushing. Finally, the tool retracts and leaves a hole with a bushing on the work piece Fig. 1e. The thickness of the bushing is usually two to three times as thick as the original work piece. This leaves enough surface area for threading. Fig 2 gives

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details of one such critical applications of friction drilling in making holes of automobile chassis.

Fig 2 Drilling of holes in chassis of an Automobile

2. Related Works

In 1923, the Frenchman Jean Claude de Valiere [1] tried making a tool that could make holes in metal by friction heat, instead of by machining. It was only a moderate success, because at that time the right materials were not yet available. Moreover, he hadn't yet discovered the right shape for this kind of tool. Overy [2] and Bak [3] discussed the design aspect of the friction drilled holes. Kerkhofs et al [4], studied the performance of coated tools used in friction drilling process. Scott F. Miller [5] and H.Wang [6] developed finite element model to explain thermo-mechanical phenomenon involved in Friction Drilling. Considerable amount of experimental works were carried out by previous researchers such as Albert J. Shih [7], [8] and Wang [6]. The process variants introduced by Gefen [9] and Head et al. [10] have captured the attention of researchers as well.

But only very few researches [11], [12] have tried out modeling and simulation of friction drilling process so far. In the present work, numerical analysis of friction drilling process has been carried out to understand temperature distribution in the work material and heat flow of the process.

3. Numerical Modeling

In friction drilling, the frictional force created by the tool produces heat and softens the material. Hence, heat flux is computed from the power given to the drilling machine and contact area between the tool and work piece. Then, the heat flux is applied to different work materials such as AISI 1020 Steel and AA 6061 T6 and the thermal behavior is studied.

3.1 Tools used

To carry out the numerical study of friction drilling process Solid Works 2014 and ANSYS 15.0 are used in the present work.

3.2 Materials selected

Owing to the applications, AISI 1020 Steel and AA 6061 T6 are selected for the numerical investigation. Their properties are given in Table 1.

Material	Thermal Conductivity **W/(m.K)**	Specific Heat **J/(kg.K)**	Mass Density **kg/m^3**
1020 Steel	**51.9**	**486**	**7870**
AA 6061 T6	**166.9**	**896**	**2700**

Table 1: Material Properties

3.3 Meshed Model

Materials are modeled in the shape of discs with outer diameter as 12 mm and thickness as 1.2 mm. The tool-work contact is at the center of the work piece with an inner diameter of 1.94 mm. The meshed model is given in Fig 3.

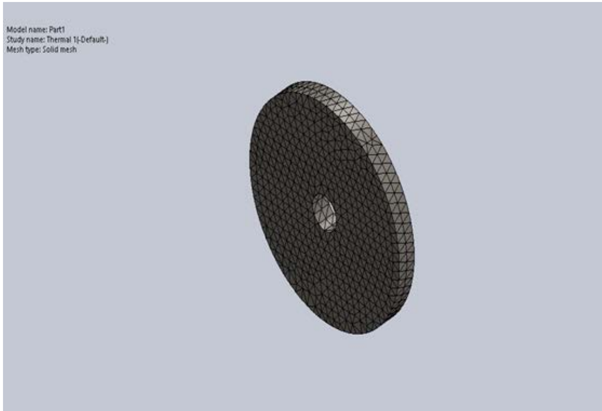

Fig. 3 Meshed Model

3.4 Heat Flux

Fig.3 gives the relation between the heat flux generated and the diameter of the tool. In the present work, maximum heat flux is considered with 2 mm drill diameter. Heat Flux is determined by dividing motor power with the contact area between tool and work piece. The process efficiency is considered as 0.5. In the numerical model, the Heat Flux 30 W/mm^2 is applied to see the thermal behavior of the work material.

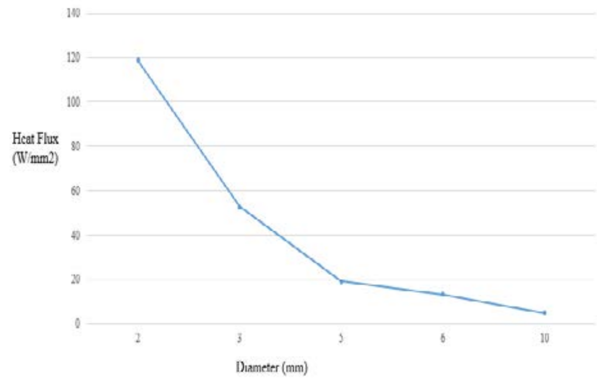

Fig 4 Effect of tool diameter on heat flux

3.5 Thermal load

The numerical analysis of Friction Drilling process is conducted on transient mode. Heat flux is applied at the center of the disc whereas the work piece is kept at 20^{0}C room temperature.

4. Results and Discussion

4.1 Heat flow in 1020 Steel

The analysis result of 1020 Steel is shown below:

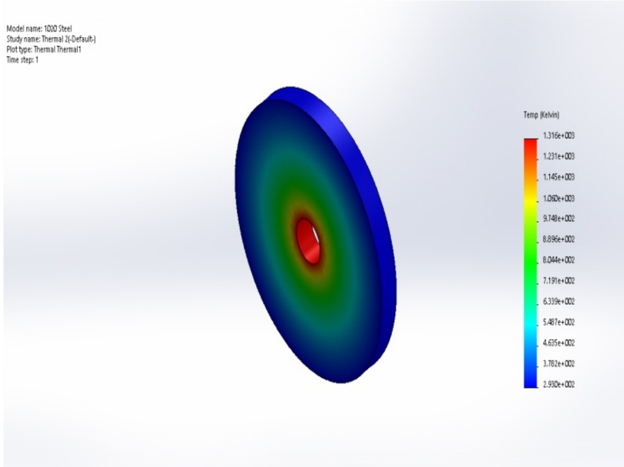

Fig. 5 Temperature Distribution in 1020 Steel during Friction Drilling

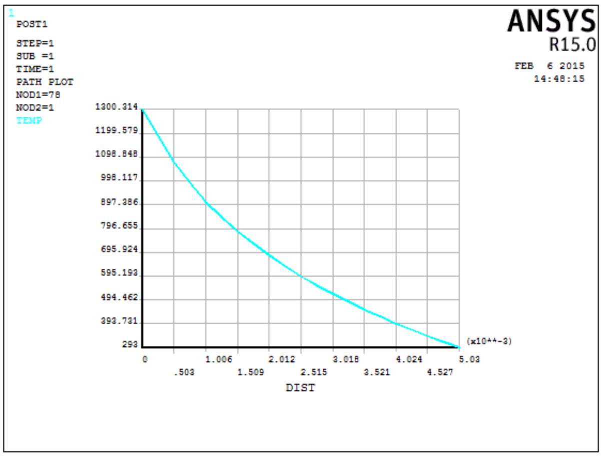

Fig. 6 Temperature vs. Distance (for 1020 Steel)

The analysis shows that the center of the disc experiences the maximum temperature i.e., 1300 K during first few milliseconds (Figure 5). It would be sufficiently high to melt the material. During the actual process the material gives in and plastic flow of the material is seen at the rear side of the work piece. Temperature distribution along the length of the work piece is shown in Figure 6.

4.2 Heat flow in AA 6061 T6

The analysis result of AA 6061 T6 is shown below:

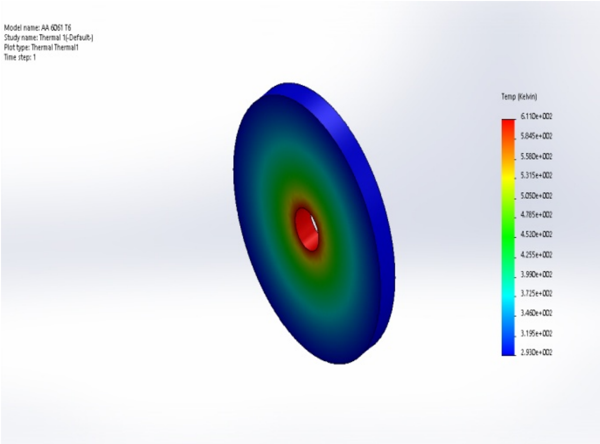

Fig. 7 Temperature Distribution in AA 6061 T6 during Friction Drilling

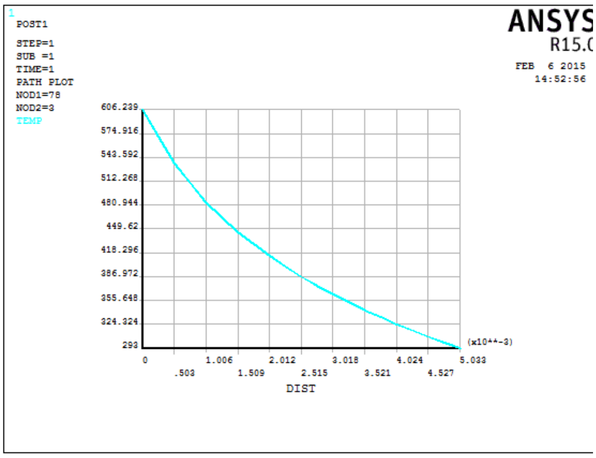

Fig. 8 Temperature vs. Distance (AA 6061 T6)

The numerical analysis shows that the center of the disc experiences the maximum temperature i.e., 606 K as in Figure 6. This is due to friction between the rotating tool and work piece. Under frictional heat the material becomes viscoplastic in nature and it flows outwardly.

In both the cases, the nodal temperature is maximum at the center and minimum at the ends (edge of the disc). But the rate of heat transfer is different for both the materials. Since the thermal conductivity of AA6061T6 is higher, heat dissipates at a faster rate. In AISI1020 steel heat is retained for some time. This may lead to the development of thermal stress. Hence, after friction drilling process, stress relieving has to be carried out.

5. Conclusion

In Friction Drilling, the heat generated from friction between a rotating conical tool and the work piece is used to soften the work material and penetrate a hole. This thermo-mechanical process is more dependent on the frictional heat developed between tool and the work piece. Hence, numerical analysis is carried out to understand the process for different work materials such as AA6061 T6 and AISI 1020 steel. Numerical results show that the point of contact between tool and workpiece experience maximum temperature near their melting point during the first few milliseconds. The material becomes viscoplastic and follows outwards during the course of the process. Hence, the material flows out to become a bushing so that subsequent internal threads could be made.

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