Investigation of Surface Texture Generated by Friction Drilling on Al2024-T6
M Boopathi, S Shankar, T Kanish

To cite this version:

HAL Id: hal-01504682
https://hal.archives-ouvertes.fr/hal-01504682
Submitted on 10 Apr 2017

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Distributed under a Creative Commons Attribution 4.0 International License
Investigation of Surface Texture Generated by Friction Drilling on Al2024-T6

M. Boopathi¹, S. Shankar², T.C. Kanish³,ᵃ

¹ – School of Mechanical Engineering, VIT University, Vellore - 632014, India
² – Department of Mechatronics Engineering, Kongu Engineering college, Perundurai - 638 052, India
³ – Centre for Innovative Manufacturing Research, VIT University, Vellore - 632014, India
ᵃ – tckanish@vit.ac.in

DOI 10.2412/mmse.1.19.706 provided by Seo4U.link

Keywords: frictional drilling, Al2024-T6, surface topography, optical micrographs, scanning electron micrographs.

ABSTRACT. Friction drilling is a nontraditional hole-making process in which, a rotating conical tool uses the heat generated by friction to soften and penetrate a thin workpiece and create a bushing without generating chips. During friction drilling most of the frictional heat is retained in the tool-workpiece interface. The effect of frictional heating is relatively prominent; this causes excessive temperatures in the workpiece and results in undesired material damage and improper bushing formation. To overcome these issues, this study investigates the surface texture generated from friction drilling process to characterize the behaviour of friction drilling on Al2024-T6 material. The surface roughness and integrity are of prime importance for any machined components in terms of aesthetics, tribological considerations, corrosion resistance, subsequent processing advantages, fatigue life improvement as well as precision fit of critical mating surfaces. In this study, in addition to the surface roughness measurement, optical microscopy and Scanning Electron Microscopy (SEM) have been carried out to gain insight into the friction drilled surface. Obtained results from the microstructures depict that the development of the microstructures are affected by the magnitude of the friction forces and the heat produced during the friction drilling process. It is also found that from the micrographs there is no direct micro-structural evidence for melting of work material in friction drilling.

1.0 Introduction. In general, more than 40% of material removal processes is drilling [1, 2]. During the traditional drilling process, it is found that chips coherence phenomenon will cause poor hole surface [3]. To solve this issues, researchers have developed a new drilling process called "Friction drilling". Friction drilling is a renewable process in which material is not cut but formed as collar and bush. During the process, the heat developed due to tool work piece interface melts the material and the axial force takes care of the rest of the job. The material is plunged into the top and bottom of the workpiece. The top is called the collar and bottom the bush. The thickness of the bushing is usually two to three times as the original workpiece. This leaves enough surface area for threading.

In the past few years, many researchers have studied friction drilling process in the aspects of thermo mechanical changes using finite element methods [4,5], tool wear monitoring [6,7] and experimental investigations [8-11]. From the literature, it is found that, only very few works have been published on the microscopic analysis of surface textures generated during friction drilling process[12,13]. They analysed the process mechanism from macroscopic point of view using the roughness profiles. The micro structural analysis was carried out for limited materials like stainless steel, titanium and few aluminium alloys only. Recently, aluminium grade Al2024T6 has been widely used in automotive and aerospace applications due to its excellent mechanical properties. Hence, this paper presents the analysis of surface texture generated during friction drilling process using surface roughness profiles. In addition to the surface roughness measurement, optical microscopy and Scanning Electron
Microscopy (SEM) have been carried out to gain insight into the friction drilled surface and micro-structural alterations on Al2024T6 material.

### 2.0 Experimental details

#### 2.1 Material used

In this study Al 2024-T6 was used in the experiments, due its high strength and low corrosion resistance. The thicknesses of the specimens were 2 mm. The chemical composition of the material is given in Table 1.

<table>
<thead>
<tr>
<th>El.</th>
<th>Cu</th>
<th>Mg</th>
<th>Mn</th>
<th>Cr</th>
<th>Fe</th>
<th>Si</th>
<th>Ti</th>
<th>Zn</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt%</td>
<td>3.8-4.9</td>
<td>1.2-1.8</td>
<td>0.3-0.9</td>
<td>Max 0.1</td>
<td>Max 0.5</td>
<td>Max 0.5</td>
<td>Max 0.15</td>
<td>Max 0.25</td>
<td>Remaining</td>
</tr>
</tbody>
</table>

#### 2.2 Experimental setup and Selection of process parameters

A CNC vertical milling machine was used for the friction drilling of Al2024T6 material. The photographic view of experimental setup is depicted in Fig. 1.

![Friction drilling experimental setup](image)

**Fig. 1. Friction drilling experimental setup.**

The experiments were planned using the Taguchi design of experiments technique. The process parameters and their levels were selected from pilot experiments and literature. Experiments were planned based on the Taguchi L₉ orthogonal array with three levels of process variables as shown in Table 2.

<table>
<thead>
<tr>
<th>Notation</th>
<th>Process parameters</th>
<th>Unit</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Spindle Speed</td>
<td>RPM</td>
<td>930 2270 4540</td>
</tr>
<tr>
<td>B</td>
<td>Feed rate</td>
<td>mm/min</td>
<td>0.01 0.02 0.03</td>
</tr>
</tbody>
</table>

### 3.0 Results and Discussions

#### 3.1 Measurement of surface finish

In the present work, the response variable is considered as average surface roughness (Ra) of the friction drilled surfaces. These surface finish measurements were carried out using Mahr brand...
surface roughness tester equipment with martalk instrument. The measured surface roughness for all the nine experiments values are shown in Table 3. Example of measured surface finish after the friction drilling (at A3, B1) is shown in Fig. 2.

![Roughness profile](image)

**Fig. 2. An example of measured surface roughness profile (Expt. no. 3)**

<table>
<thead>
<tr>
<th>Expt. No.</th>
<th>A (RPM)</th>
<th>B (mm/min)</th>
<th>Ra (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>930</td>
<td>0.01</td>
<td>1.1092</td>
</tr>
<tr>
<td>2</td>
<td>2270</td>
<td>0.01</td>
<td>1.7968</td>
</tr>
<tr>
<td>3</td>
<td>4540</td>
<td>0.01</td>
<td>0.7662</td>
</tr>
<tr>
<td>4</td>
<td>930</td>
<td>0.02</td>
<td>1.8390</td>
</tr>
<tr>
<td>5</td>
<td>2270</td>
<td>0.02</td>
<td>1.1732</td>
</tr>
<tr>
<td>6</td>
<td>4540</td>
<td>0.02</td>
<td>0.8502</td>
</tr>
<tr>
<td>7</td>
<td>930</td>
<td>0.03</td>
<td>1.4500</td>
</tr>
<tr>
<td>8</td>
<td>2270</td>
<td>0.03</td>
<td>1.5402</td>
</tr>
<tr>
<td>9</td>
<td>4540</td>
<td>0.03</td>
<td>0.8702</td>
</tr>
</tbody>
</table>

To characterize the surface obtained by the friction drilling process on Al2024-T6 material, the surface roughness profiles alone is not enough to reflect the interaction of process parameters. Therefore the corresponding optical micrographs and SEM micrographs of the workpiece surfaces were also studied and reported.

### 3.2 Optical Micrographs

Optical microscopic images of the friction drilled finished surfaces are shown in Fig. 3. It is quite clear from Fig. 3 (a) that the plastic deformation with surface lamination are present and it exhibits thin platelets of aluminum that were removed. At higher rotational speeds, these marks have been slightly removed and replaced during the friction drilling process as shown in Fig. 3 (b, c). It is due to higher speed and lower feed rate the temperature effect arranges the lay lines to become smoother and equally spaced. Normally, friction drilling process causes surface depositions throughout the surface contact. Due to the temperature generated between the tool workpiece contact, the material is being squeezed and spread over throughout the inner surface. The speed decides the uniformity of the deposition which is evident from the Fig. 3 (a-c). The surface micrograph obtained through optical microscopy does not reveal much information at micro level. In order to obtain fine surface texture details at micro and nano level, SEM techniques were employed and the results are presented in the subsequent sections.
Fig. 3. Optical microscopic image (200X) of the surface texture generated by: (a) Rotational speed = 930 RPM, Feed rate = 0.03 mm/min; (b) Rotational Speed = 2270 RPM, Feed Rate = 0.02 mm/min, (c) Rotational Speed = 4540 RPM, Feed Rate = 0.01 mm/min.

3.3 Scanning Electron Micrographs

To obtain the SEM images Carl Zeiss make FESEM-Supra 55 instrument was used. To gain insight into the friction drilled surface, SEM images were obtained and are shown in Fig. 4. From the Fig. 4(a), the damages to the interior surface of the friction drilled hole in Al2024T6 is evident. It is found that in Fig 4(a) more plastic deformation with surface de-laminations are present. Lower speeds provide lower tool rotation; it gives sufficient time for the deposition of material in the inner surfaces. During higher speed tool rotations, the material spreads uniformly and is squeezed out immediately. This will enhance the surface texture quality and will exhibit a smooth bore surface finish as shown in Fig. 4(b,c). It is also found from the SEM micrographs that there is no direct micro-structural evidence for melting of work-material in friction drilling.

Fig. 4. SEM Micrographs (1000X) of the surface texture generated by: (a) Rotational speed = 930 RPM, Feed rate = 0.03 mm/min; (b) Rotational Speed = 2270 RPM, Feed Rate = 0.02 mm/min, (c) Rotational Speed = 4540 RPM, Feed Rate = 0.01 mm/min.

Summary. Based on the experimental investigations on friction drilling process and the results, the following conclusions were drawn:

i) Friction drilling process produces better surface finish on Al2024T6 with the surface finish (Ra) value of 0.7662 µm at the following cutting conditions: Spindle speed (A3) = 22V; Feed rate (B1) = 1.5 mm.

ii) The Optical microscopy/Scanning Electron Microscopy analysis reveals that the re-crystallization of the Al2024T6 material was not observed because of the short time period of high temperature.
iii) It is observed from the SEM images, there is no direct micro-structural evidence for melting of work material in friction drilling.

**Acknowledgements.** Authors thank the VIT management for providing seed money to develop the friction drilling experimental setup at Advanced material processing lab.

**References**


Cite the paper