Study on the Cracking Time in Low-stress Precision Cropping Based on Acoustic Emission Technology

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Keywords: Low-stress precision cropping, Acoustic emission, V-shaped groove, Cracking time.

Abstract. The high-speed centrifuge and low-stress precision cropping is the technology which makes use of the stress concentration effect of the prefabricated V-shaped groove on the surface of the metal bar and relies on the expansion of the crack to achieve precision cropping. This paper applies the acoustic emission testing technology to monitor the entire process of low-stress precision cropping in order to solve the problem that the cracking time of V-shaped groove tip cannot be precisely determined during the low-stress cropping. It is concluded that the acoustic emission signal can be used to describe the crack damage process of V-shaped groove tip, providing better cross-section quality. Based on this, the cracking time of V-shaped groove tip is further determined, which better meets the requirements of low-stress precision cropping.

Introduction

In the metal manufacturing, cropping is usually the first forming process, which is widely used in the preparation procedure of die forging, cold extrusion, metal chain pin, bolts [1]. However, the traditional cropping methods such as shearing and sawing have some disadvantages to some degree, including high energy consumption, low cropping efficiency, poor cross-section quality and serious waste of raw materials. High efficiency, high quality and low consumption low-stress precision cropping technology has been gradually developed and has a very broad perspective[3]. The problem of how to determine the cracking time of V-shaped groove tip has been widely studied by scholars in low-stress precision cropping. Because it relates to the design of control curves as well as the problem of measuring the cropping efficiency[4]. In the early studies, the determination of cracking time was based on the fracture mechanics estimations and the limited empirical data, which lacked effective monitoring. Therefore, it is necessary to put forward a method to accurately determine the cracking time of the V-shaped groove tip on the metal bar. In this paper, the acoustic emission signal of the low-stress cropping machine during the cropping process for the 45 steel bar sample is monitored in real time by the acoustic emission detection device.

Introduction of Low-stress Precision Cropping System

The method of low-stress precision cropping is to preform the V-shaped groove on the surface of the bar. Then feed it into the low-stress cropping machine for cropping. The low-stress cropping machine mainly consists of five components: the transmission system, the cropping die, the trimming system, the hydraulic clamping mechanism and the body. The working principle of cropping die and the trimming system are shown in Figure 1[5]. In low-stress cropping, the converter motor with a two-stage speed increaser drives an eccentric spindle (up to 5000r/min), on which a columnar hammerhead made of anti-friction composite mounted. In this way, the bar can be loaded
continuously and without impact. In order to make the crack of V-shaped groove tip expand regularly and achieve high efficiency and low-stress precision cropping, we use the ball screw with AC servo motor to drive the shaft move upward, so that the inner diameter gradually reduce. At the same time, a surface-enhanced feed sleeve is used to fine-tune the amount of hammerhead depression. The experimental device photo of cropping machine is shown in Figure 2.

Acoustic Emission Test Process for the Crack Initiation of V-shaped Groove Tip

Principle of Detecting the Cracking Time by Acoustic Emission

Acoustic emission (AE) as a common nondestructive monitoring technique based on the rapid release of energy within a material generating transient elastic wave propagation is widely used to detect deformation, fracture and natural damages [6]. Crack initiation is the most important acoustic emission source in the precision cropping, and the energy is released in the form of elastic stress wave. To achieve the signal acquisition, the acoustic emission sensor converts the material damage signal generated by the crack propagation into an electrical signal. Several works in literature have shown that acoustic emission techniques can be used to detect and evaluate crack initiation and to show the dynamic characteristics in time [7,8]. In the early studies of various scholars, the initial crack size of V-shaped groove varied from 0.05 mm to 0.5 mm [9]. In this paper, the initial crack size of the V-shaped groove was set to 0.3 mm, and the acoustic emission technique was used to accurately determine the cracking time of the metal bar with V-shaped groove.

Experimental Method and Process

In order to obtain the acoustic emission signal of the V-shaped groove tip on the surface of the metal bar during the low-stress cropping, a full information acoustic emission analyzer with a bandwidth of 100KHz to 1000KHz is used and the influences of different stable frequency and different V-shaped groove depth on the cracking time are studied. The technical parameters of 45 steel bar with V-shaped groove are shown in Table 1. During the experiment, the inverter rapidly increases its speed to a predetermined steady frequency after the low frequency starts, it works until the bar breaks and the cropping course is completed. The acoustic emission system is set up to collect the acoustic emission signals continuously at the acquisition frequency of 3MHz. The data acquisition mode is multi-channel synchronous acquisition with the threshold set to 35dB. The acoustic emission sensor is fixed on the surface of the bar by a magnetic seat and connected to the amplifier with a gain of 40, as shown in Figure 3. In order to ensure the smooth start of the device, the initial speed of the spindle is set to 670r/min, that is, turning on the device when the inverter is at 12Hz. If the starting frequency is
too low, it will lead to failure of feeding; if the starting frequency is too high, the risk coefficient will increase, which will increase the risk of experiment.

<table>
<thead>
<tr>
<th>Technical Parameter</th>
<th>45 steel bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter /mm</td>
<td>15</td>
</tr>
<tr>
<td>Deep groove /mm</td>
<td>2.0/2.5</td>
</tr>
<tr>
<td>Bottom corner radius /mm</td>
<td>0.2</td>
</tr>
<tr>
<td>Length of bar /mm</td>
<td>240/480</td>
</tr>
</tbody>
</table>

Table 1. The technical parameters of 45 steel bar.

Figure 3. Principle diagram of acoustic emission detection for crack initiation.

Results and Discussion

In this experiment, the V-shaped groove depth of the 45 steel bar and the stable frequency are changed to explore the cracking time and compared with each other. The experimental parameters and test results are shown in Table 2, Figure 4 and Figure 5. Compared to others, the result of the fourth experiment is the best. Take the 4th crack initiation acoustic emission amplitude-time chart as an example for analysis. The result is showed in Figure 4. Turn on the experiment device at 4 seconds and it is clearly observed that as the speed of the cropping machine increases, the amplitude of the acoustic emission also increases. At 10 seconds, the acoustic emission amplitude remains relatively stable. At 19 seconds, the amplitude of the acoustic emission begins to jump violently. After removal of the bar, the tiny cracks that have just been cracked can be observed by the microscope, as shown in Figure 6. The crack length is more than 0.3mm, and the cracking time can be judged to be 15s. The crack continues to expand until the the bar breaks and the cropping completes. Through the observation of the specimen, it can be seen that the section quality of the bar is good and the section is smooth and tidy on the whole.

Table 2. Experimental parameters and test results.

<table>
<thead>
<tr>
<th>Experimental number</th>
<th>Deep groove /mm</th>
<th>Stable frequency /Hz</th>
<th>Cracking time /s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.0</td>
<td>45.0</td>
<td>53.0</td>
</tr>
<tr>
<td>2</td>
<td>2.5</td>
<td>45.0</td>
<td>35.0</td>
</tr>
<tr>
<td>3</td>
<td>2.5</td>
<td>40.0</td>
<td>48.0</td>
</tr>
<tr>
<td>4</td>
<td>2.5</td>
<td>50.0</td>
<td>15.0</td>
</tr>
</tbody>
</table>
From the comparison of the four experimental results, it can be concluded that if the frequency stability of the inverter is the same, the cracking time of the V-shaped groove of the bar material gradually decreases as the groove depth of the V-shaped increases. If the depth of the V-shaped groove is the same, the higher the stable frequency of the device is, the shorter the feeding time of the metal bar is, and the higher the cropping efficiency is.

Conclusion

1. The low-stress precision cropping system mentioned in this paper mainly consists of five components: the transmission system, the cropping die, the trimming system, the hydraulic clamping mechanism and the body, which can realize controlled expansion of the crack based on stress concentration effect of V-shaped groove and bending effect.

2. Acoustic emission technology can accurately determine the cracking time of V-shaped groove in low-stress cropping. Several experiments show that when the stable frequency is 50Hz and the groove depth is 2.5mm, the cracking time of the V-shaped groove is the least, about 15s, which can meet the industrial requirements.

3. The research results shows that proper increase of the groove depth and the stable frequency can reduce the cracking time and improve the efficiency of the low-stress precision cropping.

Acknowledgements

The authors wish to express gratitude to the National Natural Science Foundation of PR China (Approval No. 51575532) and the Fundamental Research Funds for the Central Universities (Approval No. 15CX08007A), which has supported this work.
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