

Experimental Investigation of Light Metal Scrap on Out-of-Plane Tear Ring and Shredding Test

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ABSTRACT

The objective of "Experimental Investigation of Light Metal on Out-of-Plane Tearing and Shredding Test (wall thickness less than or equal to 10mm)" is to find solutions to shredding and recovery processing of end-of-life vehicles and household appliances. By way of tensile test, the mechanical characteristics of the light metal scrap material were obtained. On the basis of strengthening effect, the constitutive relations of materials were reduced to bilinear model. Through the trousers test, Light Metal Scrap produced equal and opposite elastic-plastic bending deformation twice in the tearing process was observed. So in process of trousers tearing test, the total work external force did was mainly composed of specific tearing work and elastic-plastic bending work of trousers legs. The features of light metal scrap materials in tearing and shredding process are investigated, and the specific tearing work per unit area of new crack surface was regarded as a tearing property of light metal. The specific tearing work under different loading rate was compared and that the specific tearing work is not insensitive to loading rate in a certain range was found. The investigation showed that: The tensile specific work of rupture of light metal scrap is one order bigger than specific tearing work, meaning that tearing mode will be better on shredding recovery treatment of end-of-life vehicles and household appliances.

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INTRODUCTION

The vehicles and household appliances are mainly made up of light metal materials, and their recovery processing after scraped has become one of the important issues that people are facing. The shredding research of the light metal material is to find solutions to the problem of processing and recycling the end-of-life vehicles and household appliances effectively.

G.Schubert^[1] considered that swing hammer crusher is more suitable for crushing of light scrap metals which compose the end-of-life vehicles and household appliances. The further research^[2] indicated that the shredding mechanism of light metal by swing hammer crusher is: the impact action by shredding tools leads those small cracks in the surface of light scrap metal to stress concentration, then they are instability, extension, connection, perforation and the arc through cracks are formed. Because of the stress concentration at the tip of arc through crack and the continuous impacting, single fragment (200 mm × 200 mm) are torn off from its parent material. So, the shredding of light scrap metal can be simplified to two processes of puncture and tear. In order to study the shredding behavior of the light

scrap metal better, it is necessary to carry on deeper research on the tear behavior and performance.

For many years, tearing behavior of metals and other materials have been studied by many scholars, and some helpful achievements have been made. Y.W.Mai and B.Cotterell^[3], from the viewpoint of the essential work of fracture, have done a lot of trousers tests of ductile metal sheets and found that the bending deformation of torn legs consumed part of the whole energy. They verified the linear relationship between the tearing force of unit thickness sheet and the leg width, and by utilizing the relationship, the tearing force under the condition of ideal zero leg length was made as a material constant used to characterize the metal tear toughness. Janet S. S. Wong^[4] etc. used the "two-region" model to analyze the energy distribution of ductile polymer films in the tearing process. They pointed out that the out-of-plane tearing of ductile polymer materials also followed the EWF theory. T.Bárán^[5] and J.Karger-Kocsis^[6] studied the fracture toughness of the polymer films and discussed the essential work of fracture necessary to make the cracks destroy under modes I, II and III. And they found that because of the anisotropy of the polymer film, the essential work of fracture under mode III is bigger than that under

mode I.A.B. Martinez^{[7]~[8]} etc. analyzed three methods for energy distributions in the tearing process of polymer film by the EWF theory. ^{[9]~[10]}

On the basis of the shredding mechanism of light metal and the EWF theory, we explored the out-of-plane tearing performance of light metal material to solve the problems of shredding and recovery processing of end-of-life vehicles and household appliances efficiently.

EXPERIMENTAL STUDY

Since the light scrap metals of vehicles and household appliances are vary in mechanical property, heat treatment state and processing course, auto body sheets in different part of five kinds of scrap vehicles are randomly chosen as the experimental research object. Due to the limit of space, this thesis only gives the results of two kinds of materials here, and we can number them as material 1 and material 2 for easy describing. The primitive surface morphology of two kinds of selected materials are shown in Fig. 1, and we can see that material 1 has obvious scratch even the surface is more leveling than material 2, while the material 2 has obvious rusty spots and uneven surface.

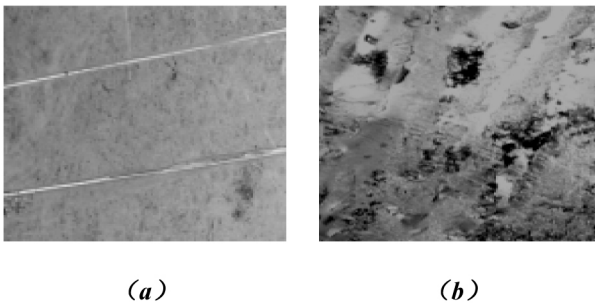


Figure 1. The primitive surface morphology of two kinds of selected materials (a) material 1; (b) material 2

Tensile Test

The concrete trade marks of the selected materials are difficult to investigate and verify, in addition, they were processed in various degrees and piled up in the open for a long time, so their mechanical performance and surface state have changed. On this ground, it is necessary to carry out the simple tensile test to obtain their mechanical performance parameters, and then it can supply the foundation for the further study of out-of-plane tearing test.

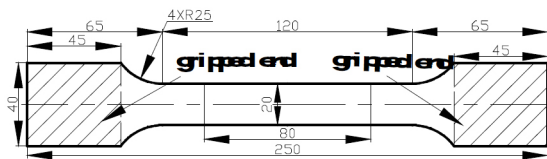


Figure 2. The tensile sample

According to the Chinese national standard GB/T 228-2002, "Metallic materials-Tensile testing at ambient temperature" tensile sheet samples are prepared by the selected auto body sheets, multiple simple tension test have done by the CSS-444100 universal testing machine, with a loading speed of 8mm/min.

Through the tensile test, the stress strain relations of the five kinds of selected scrap sheet metals have obtained, and the relations of materials 1 and 2 are shown in Fig.3. Because of the different initial processing, the light metal is strengthened in a certain degree, so the toughness reduces in some extent. It can be seen that in Fig.3, both materials 1 and 2 have no obvious surrender limit, the stress strain relations change from linear to non-linear. So, the stress $\sigma_{0.2}$ when the strain ε is 0.2% is taken as the surrender limit σ_s , that is $\sigma_s = \sigma_{0.2}$.

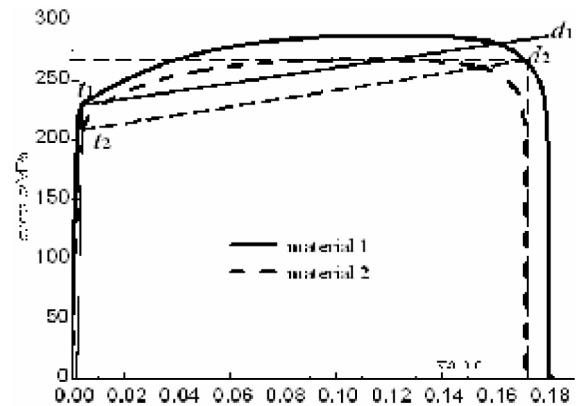


Figure 3. the stress strain relations of materials 1 and 2

Counting the strengthening function of initial processing to light sheet metal of abandoned car, we use the line $t_i d_i$ to take place of the stress strain relations after yield, where the t_i is located by $\sigma_{0.2}$ and $\varepsilon_{0.2}$, d_i is located by ultimate strength σ_b and elongation percentage after fracture, as shown in Fig.3. Finally, the material stress strain relations are simplified as bilinear models like being illustrated in Fig. 4. Strengthening elastic mould and coefficient of strengthening are given:

$$E' = \frac{\sigma_b - \sigma_s}{\delta_s - \varepsilon_s} = \frac{\sigma_b - \sigma_s}{\delta_s} \frac{E}{E - \sigma_s} \quad (1)$$

$$\lambda = \frac{E'}{E} = \frac{\sigma_b - \sigma_s}{\delta_s E - \sigma_s} \quad (2)$$