EXPERIMENTAL INVESTIGATION OF THE CONTACT STRENGTH OF POLYIMIDE AND GRAPHITE UNDER DIFFERENT TEMPERATURES

Liu Hetong¹, Ma Qinwei(∗), Ma Shaopeng¹
¹Department of Mechanics, School of Aerospace Engineering, Beijing Institute of Technology, China
(∗)Email: maqw@bit.edu.cn

ABSTRACT
The contact strength of polyimide and graphic was experimentally investigated by considering the temperature effect. A new contact area measurement method based on photogrammetry was developed for high temperature testing. The results show that the temperature has apparent influence on the contact strength of polyimide material, but almost no influence on that of graphite material. The mechanical behavior of the two materials are also investigated under different temperatures, and it can be found that there existing a positive correlation between the influence of temperature on contact strength and the influence of temperature on mechanical behaviour.

Keywords: Contact strength, line contact, contact area, high temperature, photogrammetry.

INTRODUCTION
Contact structure is very common in the mechanical engineering applications. The contact strength, with which the loading capacity of the contact structure could be evaluated, is an important parameter for the structure. For testing, the contact strength could be evaluated by the relationship between the average stress (σ̄) and the equivalent strain (ratio of the dimensions of contact area and the structure) during loading (Ma, 2013). As shown, the dimension (radius or half length) of contact area is the key to the measurement. As some contact structures may use in high temperature environment, the influence of temperature on contact strength needs to be studied. Different from the normal mechanical behaviors such as elastic parameters and tensile strength, there existing few work on the relationship between the contact strength and temperatures. Measurement of contact area in high temperature is very difficult because the methods used in normal temperature, such as indentation and piezoelectric film method (Xie, 2007) and so on all fails in high temperature.

In this paper, the influence of temperature on contact strength for two different kinds of materials, graphite and polyimide, are studied. First, a new contact area measuring method based on photogrammetry is developed, with which the contact area could be measured in high temperature. Second, the contact strength of line contact structure of the two materials are measured in different temperatures, and it is found that the contact strength of polyimide structure apparently decreases with the increasing of temperature, while the contact strength of graphite structure almost keeps constant. Finally, the correlation between the influence of temperature on contact strength and the influence of temperature on mechanical behavior are studied. It is found that there existing a positive correlation between them, i.e., for temperature sensitive materials as polyimide, the influence of temperature is apparent both on contact strength and on mechanical behavior, while for temperature insensitive materials, the temperature has no influence both on contact strength and on mechanical behavior.
CONTACT AREA MEASURING METHOD

When a cylinder contacts with a brick, the contact area is a line, and then changes to a square with load increasing. If we observe the structure in front, the contact area will change from a point to a line, as shown in Fig. 1. The distance between two contact edge points is called contact width (abbreviated as $2b_n$, $b_n$ is half contact width) and the contact area can be calculated using the contact width and the height of cylinder.

A new method to observe the contact width based on photogrammetry is presented. The images of contact area are obtained by a CCD camera, and then processed using edge detection. The intersection point of two edges of contact object is the contact edge point A and B. The distance between these two points is the contact width.

![Fig. 1 - The principle schematic diagram of contact area measuring method based on photogrammetry](image)

The way to measure the contact width is shown in Fig. 2. A light source is placed at the back of the contact structure. The specially designed aperture is used to control the amount of light which projects to the scattering screen and then a uniform light intensity behind the structure will be generated. A CCD camera in front of the structure is used to obtain the image of contact area. Great contrast between the structure and its light field around should be provided for easier edge detection.

![Fig. 2 - The schematic diagram of contact area measurement](image)

A contact experiment with graphite cylinder and graphite brick under line loading on room temperature was designed to verify the above method as shown in Figs. 3(a). The contact area was measured using both of original pressure film method and photogrammetry method. The size of graphite cylinder used in this experiment was φ70mm × 60mm and the size of brick is
100mm × 100mm × 60mm, as shown in Fig.3 (b). Pressure film (FUJIFILM R270 12M 1-E) was placed between the cylinder and the brick. A high brightness LED was used to be the light source. The cylinder was compressed using a MTS810 material testing machine in displacement control mode at a speed of 0.2 mm/min. At the same time, a high resolution CCD camera (Imperx 16M-3L, 4872×3248 pixels) was used to obtain the images with the speed of 0.2fps.

The original data obtained by pressure film method and photogrammetry method is shown in Fig.3 (c) and Fig.3 (d). The measured contact width-load curve using two different methods is shown in Fig.3 (e). The consistence of the results from the two methods verifies the effectiveness of the photogrammetry method. Because the photogrammetry method is a kind of non-contact measurement techniques so it is very suitable for high temperature test.

![Fig. 3 - The method verification experiment: (a) experiment arrangement, (b) size of the specimen, (c) original data obtained by pressure film method and photogrammetry method, (d) contact width-load curve.](image)

**EXPERIMENT AND RESULTS**

Then the contact strength of polyimide and graphic was then experimentally investigated under different temperatures. The size of polyimide cylinder used in this experiment was φ50mm × 50mm and the size of brick is 50mm × 50mm × 60mm. The size of graphic cylinder used in this experiment was as the same as in Figs. 3(b). The experimental setup is shown in Fig. 4(a) and 4(b). Light source used in this experiment is high temperature resistant lamp (up to 600º), scatter screen made by high temperature ceramic fibbers. The polyimide specimen was tested under 20º, 100º, 200º and the graphic specimen was tested under 20º, 200º, 300º and 500º. The cylinder was compressed using a MTS810 material testing machine in displacement control mode at a speed of 0.1 mm/min. The CCD camera (Imperx 16M-3L, 4872×3248 pixels) is used to obtain the images with the speed of 0.2fps.

The images data was analysed using the image processing method in section 2 and the contact area could be calculated. Then the average contact stress $\sigma_{ave}$ was obtained using contact area and load data from test machine. Finally, the contact strength of two materials could be found at the inflection point which departs from linear on the $\sigma_{ave}$–b/R curve.

The measured $\sigma_{ave}$–b/R curve and the evaluated contact strength for two kinds of materials are shown in Fig. 4. It is shown that the temperature has an apparent influence to the polyimide but almost no influence to the graphite material.
The mechanical parameters of polyimide under different temperature was tested and shown in Fig. 6(b) and Table 2. It could be found that the polyimide is a kind of temperature sensitive materials. And the reported results in literature (Xu, 1999) shows that the mechanical character of graphite is insensitive with temperature under 800º.
It can be found that there exists a positive correlation between the influence of temperature on contact strength and the influence of temperature on mechanical behavior. The positive correlation actually provides a solution to roughly assess the contact strength in high temperature just based on the mechanical behavior of materials influenced by the temperature.

CONCLUSION
The contact strength of polyimide and graphic was experimentally investigated by considering the temperature effect. A new contact area measurement method based on photogrammetry was developed for high temperature testing. The results show that temperature has an apparent influence to the polyimide but almost no influence to the graphite material which has a strong relationship with the mechanical properties of the two kinds of materials under different temperatures.

This study shows that there are substantial differences on the mechanical properties of different urogynecology meshes. Further tests should be performed in order to analyze other mechanical properties, such as flexural properties.

ACKNOWLEDGMENTS
The authors gratefully acknowledge the funding by National Natural Science Foundation of China (Grant No. 11372038 and 11402023).
REFERENCES

