euspen's 15th International Conference & Exhibition, Leuven, Belgium, June 2015
www.euspen.eu

Stress relaxation test analysis for gray cast iron

Cheng-Yen Wu [1], Sung-Mao Chiu [1],Tao-Liang Chuang [1], Liu-Ho Chiu [2],Yang-Yu Su [2], Kuan-Chueh Liao [2]

[1]*Metal Industries Research & Development Centre, Kao-Hsiung 811, Taiwan*
[2]*Department of Materials Engineering, Tatung University, Taipei 104, Taiwan*

e-mail: cywu@mail.mirdc.org.tw

Abstract
Residual stress remains in the cast iron during casting process due to the non-uniformity of cooling rate. Higher stress induced the cracking of the castings and cause irreparable loss. Industries often adopt heat treatment method to release the stress. Different heat treatment temperatures for different materials are often used. In this study, we use the stress relaxation experiments to investigate the stress relieving effect in different temperature. For FC250 grey casting iron, stress relaxation tests results of 510、530、550°C temperatures did not show significant variations in stress relieving. When the materials are in higher temperature, the intensity is lower, the existent maximum stress is also comparatively lower. Work pieces are easier to release the stress by using deformation method. Our experimental study using FC250 grey cast iron showed that there is no significant variations in hardness at 510、530、550°C temperatures.

Keywords: Cast iron, stress relaxation, casting stress

1. Introduction

Stability of the structural materials of machine tools contributes greatly to the stability of the whole machine set. If the dimensions of the materials cannot keep long time stability or the intensity is not sufficient, long time operation of the machine set will lose of the precision, reduce the yield rate, also the frequency of the maintenance of the machine set will increase. With the increase of the requirements of micromachining, demands for the precision stability of machine tools continuously raise [1]. To maintain competitiveness in global market, how to reduce the stability process for cast iron and achieve the stability effect of cast iron is critical [2]. One method to improve the stability of cast iron is to use the proper heat treatment process to release the stress of the castings and avoid the accumulation of the stress during casting process and the operation of machine tools. Deformation for the structural materials of machine tools often cannot tolerate the operations of the machine tools. Technical difficulty comes from the control of the heat treatment parameters. If the temperature and timing is not well control, probably the materials will be softened, the work pieces might be invalidated or the stress release is limited and can not reach to the dimensional stability effect [3]. In this study, we use the stress relaxation method to investigate the relationship of temperature vs. stress relieving, also we use the stress frame as the auxiliary assistance to verify the experimental results.

2. Experimental method

We select FC250 gray cast iron as the target material for our study. After high temperature casting process, we perform the tensile test, work pieces for tensile test were processed to 6mm (thickness) and 50mm (length) dimensions, 25mm round work pieces were used to perform microstructure and hardness variation tests. Morphology of graphite is the flake shape. First, we performed the high temperature tensile test to find the yielding strength, then to perform the stress relieving experiments. Work pieces are heated to annealing temperature of 510 to 550°C, tensile rate is 0.5 mm/min, then apply the stress in the plastic range of the work pieces. Tensile length are 0.8mm、0.9mm and 1.0mm, respectively, and maintain to their stable tensile length. Measurement of stress relieving was performed at different temperature. After 510、530、550°C heat treatment and holding time for 2hrs, we then perform the hardness test.

3. Results and discussion

3.1. Structure

Cast iron we used is the industrial frequently applied FC250 grey cast iron, chemical composition of the cast iron in this experiment is shown as in Table 1.

Table 1 Chemical composition of the cast iron in this experiment

Chemical Composition(wt%)				
C	Si	Mn	P	S
3.48	2.66	0.47	0.024	0.010

Cast iron of this experiment is the ASTM classified A type graphite for crystallographic analysis. Graphite is directionless dispersed in the matrix phase.

3.2. Tensile tests

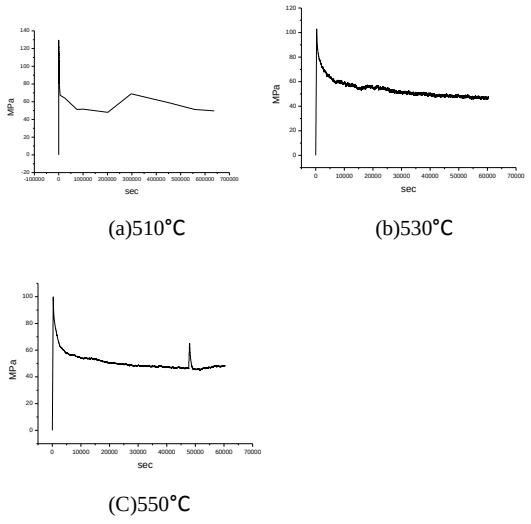
To perform the tensile tests at 510、530、550°C for FC250 gray cast iron, results are shown in Table 2. Table 2 indicates that tensile strength and 0.2% yield strength decreased with the increase of temperature.

Table 2 Tensile test results at 510、530、550℃

Tensile test	510℃	530℃	550℃
Tensile strength	531kgf	464kgf	385kgf
	175MPa	151MPa	126MPa
0.2% yield strength	509kgf	446kgf	359kgf
	166MPa	145MPa	117MPa

3.3. Stress Relaxation Test

Rapid drop down of the initial stress at 510°C comes from the error of the sliding of the grip holder during the experiment. Experiment results at 510、530、550°C showed that there is no significant variations for the stress relieving rate at three temperatures, all of them are at about 50%. Even the experiment time extend to 16 hrs, stress release rate still not be able to increase significantly, which indicated that the annealing treatment of gray cast iron under 550°C has limitation for its stress relaxation rate, even increase the tensile time, the effect is also not big. Fig. 1 indicate that at the temperature 510℃-550℃, there is a limitation of stress relieving rate, no matter how longer the work piece thermal treated.



(a)510℃ (b)530℃

(C)550℃

Figure 1. Stress relaxation test at 550℃

3.4. Effect of annealing temperature on hardness variations

Hardness tests after 510、530、550°C and 2hrs annealing treatment indicated that there is no significant variations for the hardness at 3 temperatures. Therefore, annealing heat treatment will not affect the intensity of the material and is a secure treatment temperature.

Table 3 Hardness tests after 510、530、550℃ and 2hrs treatment

510℃		530℃		550℃	
(mm)	(HB)	(mm)	(HB)	(mm)	(HB)
4.27	199	4.26	200	4.26	200
4.26	200	4.27	199	4.26	200
4.27	199	4.26	200	4.26	200

3.5. Test results of stress frame

In this experiment, we use the stress frame as the target for the casting stress study of FC250 gray cast iron. Middle cross bar of the stress frame is thicker (20mm), the side frame is thin (8mm). Since the middle cross bar is thick and close to the center of sand mold, the cooling rate is slower, therefore the central cross bar bears tensile stress, and the thin cross bar on both side bears compression stress. We then measure the length variations on the upper 2 points before and after cutting of the central cross bar. With the assistance of plastic coefficient, stress of the stress frame before the cutting of central cross bar could be obtained. Table 4 are the stress values of the stress frame before and after heat treatment and show that the stress elimination rate of the stress frame is higher than the stress relaxation test, possibly because the whole stress frame under annealing conditions could be distorted (not only close to central column), and the distortion of the stress relaxation test will completely depend on the test piece itself. At this temperature, distortion system of the material interior has limitation, induce the stress elimination rate lower than the whole distorted stress frame at that temperature.

Table 4 The stress of the stress frame before and after 550℃ annealing treatment.

before	after
124.9MPa	28.5MPa

4. Results and discussion

1. FC250 gray cast iron we used in this experiment is the ASTM classified A type graphite. Phases of the matrix mainly are the pearlites and few ferrites.
2. Tensile strength and yield strength decreased with the increase of temperature at 510°C、530°C、550°C.
3. Hardness for FC250 cast iron did not significantly decrease after 510、530、550°C heat treatment for 2 hrs in this experiment. (20mm)
4. Casting stress for the design of middle cross bar (20mm) and side bar (8mm) in this experiment is about 124Mpa. The stress of the stress frame for FC250 is about 124Mpa in this experiment.

References

[1] T. Murakami, T. Inoue,H. Shimura,M. Nakano,S 2006. Sasaki. Advanced Manufacturing Research Institute, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki, Japan **305**-8564

[2] G A Webster, C M Davies,K M Nikbin. International Journal of Solids and Structures 2010 **47**:881-886.

[3] K Kocatepe, M Cerah,M Erdogan. *Materials & Design*. 2007 **28**:172-181.

[4] B-Y Jeong, J-H Chang,M-H Kim. *Surface and Coatings Technology* 2010 **205**:896-901.

[5] Chiachin Lina, Yuchoung Changb, Kunyi Liangb Chinghua Hunga. *Applied Thermal*. Volume 25, 2005, Issues 11–12, August, **1724**–1739