Creep behaviour analysis of brass bar on variable temperature

Md Danish Iqbal¹, Premanand S Chauhan¹, Avadesh K Sharma² and Prem Prakash Pandit¹
¹IPS College of Technology and Management, Gwalior, India
²Rajkiya Engineering College, Mainpuri, India

E-mail: iqbal.azmi1997@gmail.com

Abstract. This paper presents the behaviour of Creep of Brass bar at different temperatures i.e. 300°C, 500°C and 600°C. It is necessary to perceive the behaviour of creep of Brass bar at different temperature conditions because this copper and its alloy are used in several high temperature applications. Results indicate that temperature has significant effect on the rate of deformation and life of component.

Keywords: creep deformation, Brass, Creep at different temperature conditions

1. Introduction

Creep is slow and permanent deformation under constant load or due to its self weight with respects to the time. It is time and temperature dependent phenomenon. Creep is also depending upon type and magnitude of load.

The progressive deformation of a metal, under a constant load is known as creep. This experiment is most necessary to know the performing life of the machine, heat exchanger, condenser components which are come under the action of creep. There are two aspects to the creep of the machine components, One is the long time creep behavior when the components is expected to be in service of number of years under various weather and loading conditions, the other is the short time transient creep behavior. It is always seen in metals like Aluminium, Brass, steel, copper, etc and their alloys at increased temperature. But some metal like zinc, tin, lead and their alloys also creep at room temperature. [1]

It has been found that some organic metals such as plastics and rubber are very sensitive to creep.

It is necessary to perceive the creep behaviour analysis of brass bar on dependent temperature because composition of brass bar contains a multiple of defects such as cavities, non-metallic contaminates, lead clustering, surface cracks and zinc segregation into foundry process. At room temperature, the rate of distribution of these defects remains almost uniform, therefore At high temperature additional deformation mechanism come into play that are not operative at lower temperatures. For structures operating at elevated temperature, then it need to factor in high temperature failure mode of particular significance is
diffusional flow, which does not happen at low temperature. Hence, at lower temperature materials failure can be regarded as primarily time dependent.

However at elevated temperature vacancies in the crystal structure can disperse to the location of a dislocation and cause the dislocation to move faster to a next slip plane thus, allowing for more deformation to happen. Therefore, creep deformation accelerates with raise in temperature of Brass. The temperature range in which creep deformation may occur differs in a variety of materials. [2]

The creep test is generally performed by applying a static load to one end of the lever system. The other end is attached to the specimen, under test in the thermostatically controlled furnace or held at constant temperature.

2. Literature Review

A. Hattori, S. Inoue, T. Miyagawa and M. Fujii’s, (1995) Paper on a study of bond creep behavior of FRP bars embedded in concrete, In this paper experiment has done and result obtained that laboratory and field pull out test five types of cement grouted glass fiber reinforced concrete plastic anchor bolt installed in concrete blocks and rock mass. Total 68 GPRP (Grouted Fiber Reinforced Plastic) and 26 steel anchors with 3 length had tested the bond strength between the bars, bond stress, slip behavior, critical bond length cement grouted GFRP are in comparison to steel bars bolts. [3]

Daniele Barbera, Haofeng Chen & Yinghual Liu, (2016) paper published in international journals of pressure vessels and piping on the aluminum alloys based metal matrix composite that is based on creep fatigue this is broadly accepted and used in varies types structure and component widely adopt due to costly manufacturing process and complex micro structural behavior. When they subjected to fluctuating load conditions the structure response of MMC is not trivial, and become more difficult when elevated temperature load is involved. [4]

J. Kloewer & G. Sauthoff, (1991) paper published in Zeitschrift fuer Metallkunde on Creep behavior of lamellar nickel-iron aluminum alloys was studied as function of stress, temperature, lamellae spacing and lamellae orientation. For large lamellae spacing the creep resistance follow a rule of mixture whereas for small spacing there is an additional strengthening effect of the interphase boundaries which proportional to the reciprocal lamellae spacing cyclic load conditions the structure response of MMC is not trivial, and become more difficult when high temperature load is involved. [5]

D.Pilo & W.Reik, (1979) German scholar studied on cyclic induce creep of a plain carbon steel at room temperature with specimen composition A German grade Ck 45 carbon steel round bar medium carbon steel. In this research, scholar finally reached up to the point that, fatigue failure analysis done but desire result is not achieved various experiment has to be done in secondary way “0.2% cyclic creep strain”. Results oriented that achieve and outcome achieve by Haig diagram which provided that more appropriate information available in stress amplitude & mean stress. [6]

S.C.Tjong & Z.Y. Ma, (1997) experiment has done on behavior of composite of aluminum-matrix with SiC, and Al2O3. The results obtain that the pure aluminium based composite exhibits an apparent stress exponent of 8.9 and 9.5 respectively at 573K and 623 K and apparent activation energy of 177 KJ mol. [7]

In these papers we have found that there were several works have been done on room temperature or fixed temperature, we could not find out the material creep behavior analysis in gradual manner to low temperature to high temperature, what is the exact material behavior on various scale of temperature.
Work has been carried out on pressure vessel, aluminum, grouted reinforced plastic bolt, cryogenic creep macro structures all experiment find that exact point determining process carried out with different method.

Since, researchers have been done creep behaviour on room temperature or fixed temperature, Hence work can be done on creep behaviour analysis of Brass at different temperature.

3. Experimental Work

The specimen is made of Brass with the following chemical composition as shown in Table 1. Specimen of 10.7 mm diameter rod is manufactured by Parting, Center less grinding & threading. Specimen is shown in fig 1. and the Schematic diagram of Specimen is shown in fig 2.

| Table: 1. Chemical composition of brass (wt. %) |
|---|---|---|---|---|---|---|---|---|---|
| Cu | Zn | Pb | Fe | Al | Mn | S | Sn | Ni |
| 54.0 | 40.79 | 3.03 | 0.47 | 0.44 | 0.098 | 0.004 | 0.75 | 0.260 |

Figure 1. Specimen
Figure 2. Schematic diagram of specimen

The creep testing had been conducted on the universal creep testing machine with a thermostatically controlled furnace Whose Pictorial Figure shown in fig 3. This type of machine has Lateral support of moving crosshead and precision sliding bearing on four hard chromium. The specimen had been positioned in the machine between the grips of the creep testing machine, and gauge length is placed in thermocouple furnace so that heat can be providing to the specimen.

These are the most important parameters of creep testing machine:

- Providing strain rate to the specimen
- Providing desired temperature
- Reading of displacement with respect to time
- Accuracy

The specifications of the machine are as follows:

- Make : Enkay Enterprises
- Model : CT 100
- Load Capacity : 50 KN
- Test area depth : Unlimited
- Test area-width between drive screw : 610 mm
- Test speed range : 0.001 mm/h to 100 mm/h
- Return speed : 100 mm/min
- Crosshead speed accuracy : +/- 0.1% of Setting ( no load or constant load averaged over 10 mm
- Resolution of stroke encoder : 0.068 nm
- Power requirements : 230 VAC, 1 KVA

The creep test is conducted by using Creep testing machine in which a constant strain rate of 0.05 mm/min is apply, often by the simple method specimen is meshed between the gripers of the machine and suspending weight to the specimen, weight is automatically controlled by the machine, and the specimen is surrounded by thermostatically controlled furnace. The temperature being controlled by
thermocouple attached near the gauge length of the specimen. The displacement of the specimen is measured by a very perceptive extensometer. The outcome of the experiment is plotted on a graph between displacements (mm) versus time (hrs).

Figure 3. Creep testing machine

The procedure followed to conduct experiment is as follows:

- The Specimen is measured throughout the gauge length before experiment.
- The initially load is applied to the specimen which is observed frequently since, the magnitude of load is very less so it is neglected.
- The specimen is heated to the required temperature within the gauge length.
- Strain rate of 0.05 mm/min is applied to the specimen.
- The expansion of the specimen is measured at frequent interval till fracture.

3.1. Specimen Imported in ANSYS Software

ANSYS is universal intention software, used to create interactions of all disciplines of physics, fluid dynamics, structural design, electromagnetic & heat transfer for engineers. ANSYS R 16.2 is used to find simulation results. The figure 4 to figure 7 shows the specimen in ANSYS
Figure 4. Specimen imported in ANSYS

Figure 5. Temperature applied to the specimen (300°C)

Figure 6. Temperature applied to the specimen (500°C)

Figure 7. Temperature applied to the specimen (600°C)

4. Results and Discussion

The experimental results are evaluated by the Creep testing machine experimentally. The combined results of 300°C, 500°C & 600°C are shown in Table 2 and the graph in Fig 8.
Table: 2. Combined Experimental Results of 300°C, 500°C & 600°C

| S. No. | Time (hrs) | 300°C | 500°C | 600°C |
|--------|------------|-------|-------|-------|
| 1.     | 0.02       | 0.003 | 0.033 | 0.003 |
| 2.     | 0.3        | 0.239 | 0.281 | 0.25  |
| 3.     | 0.6        | 0.653 | 0.522 | 0.616 |
| 4.     | 0.9        | 0.795 | 0.766 | 0.746 |
| 5.     | 1          | 0.8   | 0.816 | 0.819 |
| 6.     | 1.3        | 0.907 | 0.93  | 1.001 |
| 7.     | 1.6        | 1.019 | 1.04  | 1.194 |
| 8.     | 1.9        | 1.121 | 1.15  | 1.325 |
| 9.     | 2          | 1.148 | 1.187 | 1.371 |
| 10.    | 2.3        | 1.237 | 1.298 | 1.542 |
| 11.    | 2.6        | 1.322 | 1.415 | 1.739 |
| 12.    | 2.9        | 1.412 | 1.533 | 1.953 |
| 13.    | 3          | 1.438 | 1.582 | 2.037 |
| 14.    | 3.3        | 1.53  | 1.733 | 2.265 |
| 15.    | 3.6        | 1.616 | 1.859 | 2.506 |
| 16.    | 3.9        | 1.702 | 1.977 | 2.746 |
| 17.    | 4          | 1.725 | 2.038 | 2.833 |
| 18.    | 4.3        | 1.794 | 2.193 | 2.999 |
| 19.    | 4.6        | 1.831 | 2.321 |       |
| 20.    | 4.9        | 1.923 | 2.455 |       |
| 21.    | 5          | 1.949 | 2.509 |       |
| 22.    | 5.3        | 2.012 | 2.672 |       |
| 23.    | 5.6        | 2.081 | 2.818 |       |
| 24.    | 5.9        | 2.147 | 2.935 |       |
25. 6  2.17
26. 6.3 2.233
27. 6.6 2.299
28. 6.9 2.368
29. 7  2.388
30. 7.3 2.457
31. 7.6 2.517
32. 7.9 2.606

After the experimental work graph of creep curve between displacement versus time is drawn which is shown in figure 8. It is noted that, as temperature increases fracture of specimen takes place frequently, 7.9 hours for 300°C, 5.9 hours for 500°C & 4.3 hours for 600°C. Also elongation of specimen increases as increase in temperature. The Creep curve in all the cases (at 300°C, 500°C & 600°C) shows two stages in one primary stage and other secondary stage, primary stage has high creep strain rate where as secondary stage has low creep strain rate as compared to primary stage.
4.1. ANSYS Results

Simulation results have been evaluated by conducting the FEM tool ANSYS workbench. The Comparison of Experimental Results & Simulation Results at 300°C, 500°C & 600°C is shown in Table 3, deformation in figure 9 to figure 11 and the graph in figure 12 to figure 14.

**Figure 8.** Creep curve at 300°C, 500°C & 600°C

**Figure 9.** ANSYS analysis of the bar at 300°C

**Figure 10.** ANSYS analysis of the bar at 500°C

**Figure 11.** ANSYS analysis of the bar at 600°C

**Table 3.** Comparison of Experimental Result & Simulation Result of 300°C, 500°C & 600°C
| S. No. | Time (hrs) | 300°C | 500°C | 600°C |
|--------|------------|-------|-------|-------|
|        |            | Experimental | Simulation | Experimental | Simulation | Experimental | Simulation |
| 1      | 0.2        | 0.003 | 0.006 | 0.033 | 0.062 | 0.003 | 0.005 |
| 2      | 0.3        | 0.239 | 0.361 | 0.281 | 0.414 | 0.25 | 0.394 |
| 3      | 1.6        | 1.019 | 1.141 | 1.04 | 1.173 | 1.194 | 1.338 |
| 4      | 2.3        | 1.237 | 1.359 | 1.298 | 1.431 | 1.542 | 1.686 |
| 5      | 3.6        | 1.616 | 1.738 | 1.859 | 1.992 | 2.506 | 2.65 |
| 6      | 4.3        | 1.794 | 1.916 | 2.193 | 2.326 | 2.999 | 3.143 |
| 7      | 5          | 1.949 | 2.071 | 2.509 | 2.642 |
| 8      | 5.6        | 2.081 | 2.203 | 2.818 | 2.951 |
| 9      | 5.9        | 2.147 | 2.269 | 2.935 | 2.292 |
| 10     | 6.9        | 2.368 | 2.49 |
| 11     | 7.3        | 2.457 | 2.579 |
| 12     | 7.6        | 2.517 | 2.639 |
| 13     | 7.9        | 2.606 | 2.728 |
Figure 12. Comparison of creep curve of experimental result & simulation result at 300°C

Figure 13. Comparison of creep curve of experimental result & simulation result at 500°C
5. Conclusion

It is concluded from the analysis on Universal Testing Machine that from the creep curve of Brass that the stage primary and tertiary are short time periods as compared to secondary stage which represents the entire life period of the specimen. A little consideration will show that this period is of great importance, because the life time of machine component depends upon the rate of this extension. If any attempt is made to decrease the tensile strength, the secondary stage will decrease accordingly. It is thus obvious, that in such cases the design must be based on the assumption of a definite period of service and definite amount of permissible distortion.

This Experiment is highly beneficial for the power plant, boiler application where pressure parts of boiler are very sophisticated function work under very high temperature, creep behavior analysis is very to engineer decide the material according to the application, without creep consideration is not possible to design of any component that for high temperature.

6. References

[1] R.S khurmi & R.S Sedha Material Science book S. Chand Publication. 165-167
[2] https://www.quora.com/What-is-the-physical-significance-of-a-creep-test
[3] A.Hattori, Inoue, S., Miyagawa, T., & Fuji, M. (1995). A study on bond creep behaviour. Non-Metallic (FRP) Reinforcement for Concrete Structures: Proceedings of the second international RILEM symposium FRPRCS 2 172-179.
[4] Barbera, D., Chen, H., & Liu, Y. (2016). Creep-fatigue behavior of aluminum alloy based metal matrix composite. International Journal of Pressure Vessels and Piping 139 159-172.
[5] Kloever, J., & Sauthoff, G. (1991). Creep behaviour of directionally solidified lamellar nickel-iron-aluminum alloys. Zeitschrift fuer Metallkunde 22 510-518.
[6] Pilo, D., Reik, W., Mayr, P., & Macherauch, E. (1979). Cyclic induced creep of a plain Carbon Steel at room temperature. *Fatigue of Engineering Materials and Structures* **1** 281-295.

[7] S.C.Tjong, & Z.Y.Ma. (1997). The high-temperature creep behaviour of aluminium matrix composites reinforced with SiC, Al2O3 and TiB2 particles. *Composites Science and Technology* **57** 697-702.