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Heat Treatment of Aluminum Alloy 7449

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***Abstract*—**Aluminum alloy has an extensive range of industrial application due to its consistent mechanical properties and structural integrity. The heat treatment by precipitation technique affected the Magnesium, Silicon Manganese and copper crystals dissolved in the Aluminum alloy. The crystals dislocated to precipitate on the crystal's boundaries of the Aluminum alloy when given a thermal energy increased its hardness. In this project various times and temperature were varied to find out the best combination of these variables to increase the precipitation of the metals on the Aluminum crystal's boundaries which will lead to get the highest hardness. These specimens are then tested for their hardness and tensile strength. It is noticed that when the temperature increases, the precipitation increases and consequently the hardness increases. A threshold temperature value ($264C^0$) of Aluminum alloy should not be reached due to the occurrence of recrystalization which causes the crystal to grow. This recrystalization process affected the ductility of the alloy and decrease hardness. In addition, and while increasing the temperature the alloy's mechanical properties will decrease. The mechanical properties, namely tensile and hardness properties are investigated according to standard procedures. In this research, different temperature and time have been applied to increase hardening.The highest hardness at 100°c in 6 hours equals to 207.31 HBR, while at the same temperature and time the lowest elongation equals to 146.5.

***Keywords*—**Aluminum alloy, recrystalization process, heat treatment, hardness properties, precipitation, intergranular breakage.

I. Introduction

ALUMINUM alloys are widely used in the production of automotive component, building, marine, aerospace and electrical industries because of their light weight, corrosion resistance, ductile, and easy forming. Pure aluminum has a tensile strength of about 90 MPa. This can be improved by cooling and alloying it with other materials, where the most useful alloying elements for aluminum are copper, silicon, manganese, magnesium, and zinc. AL-7xxx alloys have numerous benefits including medium to high strength, formability, wilding-ability, and corrosion resistance. Thus it can be used in a variety of applications including marine, pressure vessels, road transport, transport of ammonium nitrate, and chemical plants.

Many authors extensively weakened heat treatment of aluminum alloys. Dorward and Bouvier [1] illustrated the essential effects of manganese and chromium, especially that these alloying accumulation prevent the precipitation of magnesium and silicone on grain boundaries; as a result it reduces the intergranular breakage targets. The significant effect of manganese on the hardness is the integration of deformation, leading to reduction in the intergranular breakage. In addition, it was noted that a refined grain size, as influenced by manganese (a grain structure control agent), was another positive effect. Also Markandeya and Sarma [2] concluded that the age hardening through precipitation hardening strengthens AL-Cu and AL-Si alloys. Precipitation hardening is the most common heat treatment process used in improving the mechanical properties of aluminum alloys, However interaction of the different phases in the alloy systems during precipitation and how the interaction affects their mechanical properties have not been studied. While Zhen [3] Verified the importance of time that is applied on heating treatment and artificial aging with the presence of deformation.

In another study Sun [4] emphasize that the deformation impact on the samples of cooling and aging has positive effect on hardness and strength. CAI [5] combined the mechanical processing and aging concluding that this way was more effective than the conventional aging in both terms; the mechanical property and the highest time. But Murizam and shamsul [6] studied the field of the artificial aging process reactions under different temperatures on recycled 319 series aluminum alloy. It was inferred that the highest solution temperature applied had accelerated the age-hardening response of recycle Aluminum alloy 319 series, believed that the higher temperature solution treatment may attribute to fully dissolve the copper-rich phase in the aluminum matrix as shown in the resistivity measurement.

The main objective of the current work is to study the result of the Aluminum alloy 7449 to precipitation hardening (age hardening and effect on the mechanical properties), AL-7449 made in France in 1994 its density 2.85 Kg/m^3 x $10^{3.}$

II. Experimental Procedure

The test specimens were adapted by using wrought 5023 aluminum cylindrical bars with the dimensions in the tensile test of length L= 140mm and diameter D= 8mm where the dimensions in the hardness test of diameter D= 50mm and thickness T= 20mm. The equipments were used in this work are the electrical resistance furnace and the universal testing machines.

In heating treatment for aluminum alloy all the specimens are heated at 520°C for 2h and followed by quenching in water in the room temperature after quenching the specimens were kept in a freezer to avoid the natural aging. After heating of the specimens at 100, 150,200,230, 280, and 310°C for 2, 4, and 6 hours they were cooled out. It was clear to notice the effect of the various mechanical properties.

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TABLE I
CHEMICAL COMPOSITION OF THE INVESTIGATED ALLOY

Al	Other	Zn	Mg	Mn	Cu	Fe	Si	alloy
86.98	0.15	8.5	1.8	0.20	2.1	0.15	0.12	7449

III. RESULT AND DISCUSSION

Table II shows the hardness that increases with time and temperature before the crystallization degree. Highest hardness at 100°c for 6 hours due to high precipitation and high dislocation (disturbs in lattice). After crystallizations temperature, the number of particle decreases but the size increases, this put obstacles to move the dislocation and the diffusion of the atoms. But the hardness increased apparently when the temperature reached 280°c, 310°c after six hours heating. This long time helped precipitation to occur.The increase in the mechanical properties (yield stress, hardness and elongation) appeared at 100°c for 2 hours due to the acceleration diffusion of vacancies and dislocation in the lattice. Ultimate stress increases because of the increasing the density of dislocation at grain boundary. Elongation is decreasing with time because of increasing precipitation. At 250°c temperature the elongation increases with time with the particle growing while at 280°c the highest elongation occurred because of the increase in particle growth. On the other hand it can be seen that high increase in particle growth were noticed because of the decrease in elongation.

TABLE II
MECHANICAL PROPERTIES FOR SPECIMEN7449

temperature °C	Time hr	hardness HBR	ultimate stress Mpa	proportional limit Mpa	elastic modulus Mpa	0.20%yield stress Mpa	elongation
520	2	100.72	274.120	136.861	333.809	0.9223	252.7143
100	2	115.58	258.405	74.199	257.468	7.913	269.9286
100	4	105.84	250.845	115.974	283.368	0.4252	198.7857
100	6	207.31	251.044	146.210	557.695	1.556	146.5000
150	2	98.27	253.829	120.748	279.822	0.4915	239.0714
150	4	87.20	226.974	102.447	299.932	0.2316	224.000
150	6	150.98	228.964	67.834	202.601	0.3590	217.8571
200	2	103	256.415	115.576	237.343	0.1645	256.6429
200	4	114.38	273.324	46.549	200.943	0.2594	235.4286
230	2	77.30	264.174	74.398	255.597	1.019	193.1429
230	4	89.26	262.980	100.855	305.410	0.7712	246.8571
230	6	85.19	276.109	120.947	330.171	0.0608	163.6429
280	2	86.39	272.329	96.877	290.882	0.5350	201.0714
280	4	62.86	255.421	104.038	279.646	0.3777	270.3571
280	6	114.38	275.313	117.963	332.816	0.8675	248.4286
310	2	59.8	275.512	56.893	243.480	0.5758	243.6429
310	4	88.02	263.975	106.425	338.771	0.1106	173.3571
310	6	109.73	274.319	113.189	352.409	1.154	236.4286

Fig. 1 shows the ultimate stress of 274.120 Mpa., proportional limit of 136.861Mpa elastic modulus of 333.809 Mpa., 0.20% yield stress of 0.9223 Mpa and elongation percentage of 252.7143 percent of the original specimen.

Fig 2 (a) shows the ultimate stress of258.405 MPa., proportional limit of74.199 Mpa., elastic modulus of257.468 Mpa., 0.20% yield stressof7.913 Mpa.,and the percentage of elongation equals 269.9286 percent. Fig. 2(b) shows the ultimate stress of250.845 MPa., proportional limit of115.974 MPa., elastic modulus of 283.368 MPa., 0.20% yield stress 0.4252 MPa., and percent elongation of198.7857 percent. But figure 2(c) shows the ultimate stress of 251.044 Mpa., proportional limit of 146.210 Mpa., elastic modulus of 557.695 Mpa., 0.20% yield stress 1.556 Mpa., and percentage of elongation equals 146.5000.

Fig 3 (a) shows the ultimate stress of 253.829 MPa., proportional limit of 120.748 MPa., elastic modulus of 279.822 MPa., 0.20% yield stress of 0.4915 MPa., and percentage ofelongation equals to 239.0714.While figure 3(b) shows the ultimate stress of 226.974 MPa., proportional limit of 102.447 MPa., elastic modulus of 299.932 MPa., 0.20% yield stressof 0.2316 MPa., and percentage of elongation equals to 224.0000 percent. But Fig. 3(c) shows the ultimate stress228.964 MPa.

Fig. 4 (a) shows the ultimate stress of256.415 MPa., proportional limit of115.576 MPa., elastic modulus of237.343 MPa., 0.20% yield stressof0.1645 MPa., and percentage of elongation equals 256.6429 .While figure 4(b) shows the ultimate Stress of273.324 MPa., proportional limit of46.549 MPa., elastic modulus of200.943 MPa., 0.20% yield stress of0.2594 MPa., and percentage of elongation equals to 235.4286. But Fig. 4 (c) shows proportional limit of67.834 MPa., elastic modulus of202.601 MPa.,0.20%,yield stress of0.3590 Mpa., and percentage of elongation equals 217.857.

Fig. 5(a) shows the ultimate stress of264.174 MPa., proportional limit of74.398 MPa., elastic modulus of255.597 MPa., 0.20% yield stress of1.019 MPa.and percentage of elongationof193.1429.While figure 5(b) shows the ultimate stress of 262.980 MPa., proportional limit of100.855 MPa., elastic modulus of305.410 MPa., 0.20% yield stressof0.7712 MPa.,and percentage of elongation of246.8571. But Fig. 5(c) showsthe ultimate stress of276.109 MPa., proportional limit of120.947 MPa., elastic modulus of330.171 MPa., 0.20% yield stress of0.06083 MPa., and percentage of elongation of 163.6429.

Fig. 6 (a) shows the ultimate stress of272.329 MPa., proportional limit of 96.877 MPa., elastic modulus of290.882 MPa., 0.20% Yield Stressof0.5350 MPa., and percentage of elongation of 201.0714.While figure 6(b) shows the ultimate stress of 255.421 MPa., proportional limit of104.038 MPa., elastic modulus of279.646 MPa., 0.20% yield stress of 0.3777 MPa., and percentage of elongation of 270.3571.But Fig. 6(c) shows the ultimate stress of 275.313 MPa., proportional limit of 117.963 MPa., elastic modulus of 332.816 MPa., 0.20% yield stress of 0.8675 MPa., and percentage of elongation of 248.4286.

Fig. 7 (a) shows the ultimate stress of275.512 MPa., proportional limit of56.893 MPa., elastic modulus of243.480 MPa., 0.20% yield stressof0.5758 MPa., and percentage of elongation of 243.6429.While figure 7(b) shows the ultimate stress of 263.975 MPa., proportional limit of 106.425 MPa., elastic modulus of 338.771 MPa., 0.20% yield stress of 0.1106 MPa., and percentage of elongation of 173.3571.Butfigure 7(c) shows the ultimate stress of 274.319 MPa., proportional limit of 113.189 MPa., elastic modulus of 352.409 MPa., 0.20% yield stress of 1.154 MPa., and percentage of elongation of 236.4286.

IV. Conclusion

It can be concluded that the highest hardness was at 100°c and 6 hours which is equal to 207.31 HBR, while at the same temperature and time, the lowest elongation equals 146.5.The highest elongation was at 280°c and 4 hours and equals to 270.357, while the hardness equals 62.82 HBR. The highest yield stress was at 100°c and 2 hours and equal to 7.913 Mpa indicating yield stress hardness and increase of elongation at that point.

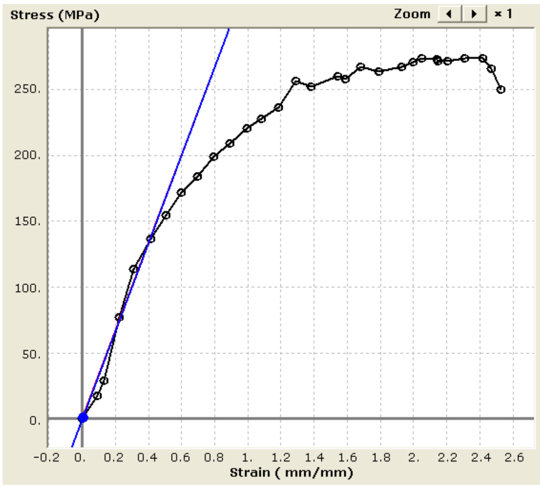

Fig. 1 Stress strain diagram of the original specimen

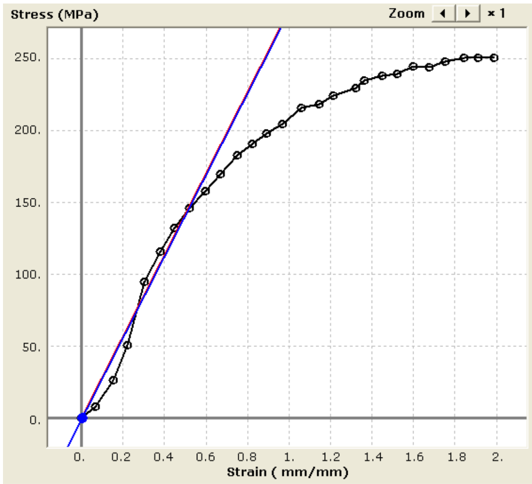

Fig. 2 (a) Stress strain diagram at 100° and 2 hours

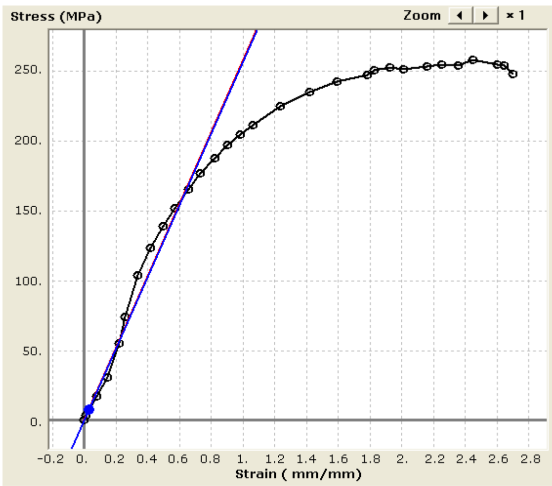

Fig. 2 (b) Stress strain diagram at 100° and 4 hours

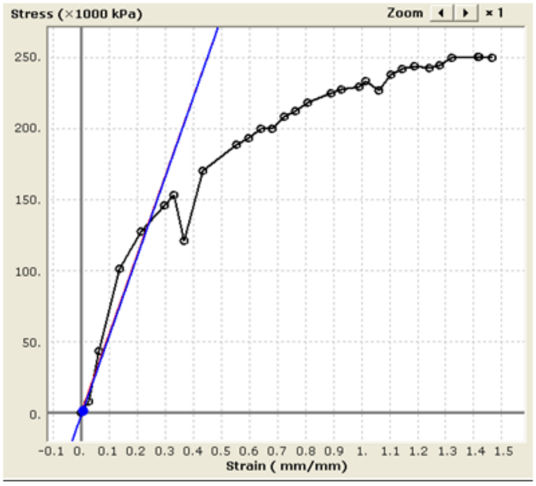

Fig. 2 (c) Stress strain diagram at 100° and 6 hours

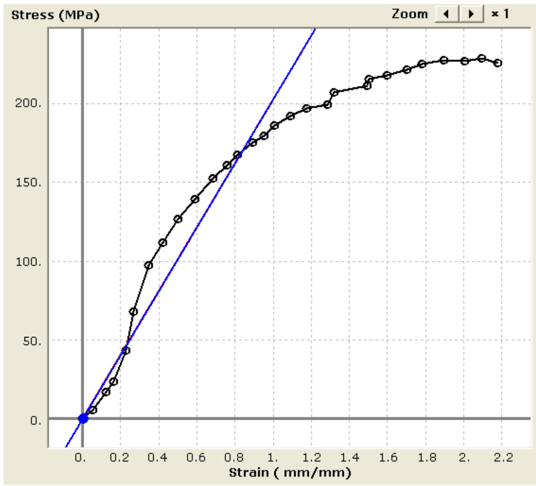

Fig. 3 (c) Stress strain diagram at 150° and 6 hours

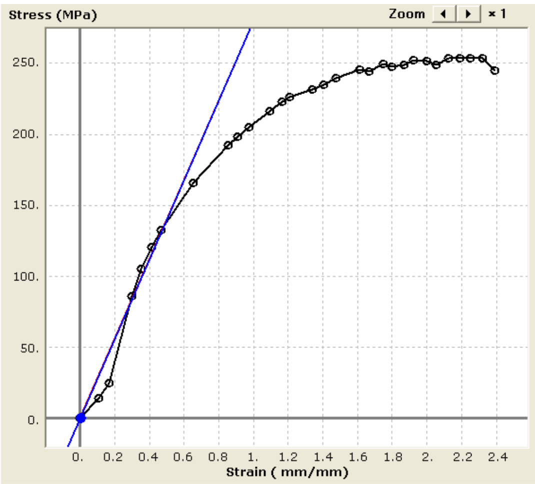

Fig. 3 (a) Stress strain diagram at 150° and 2 hours

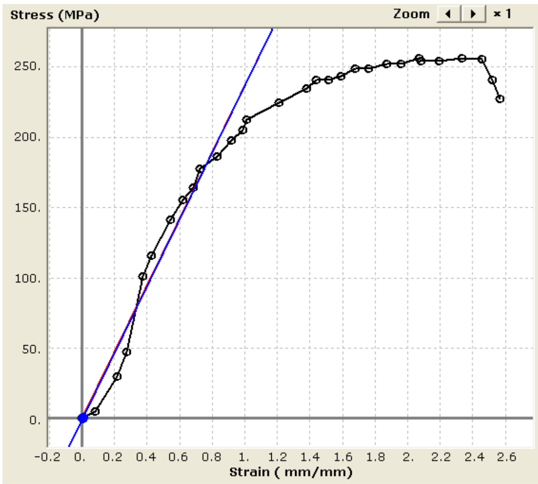

Fig. 4 (a) Stress strain diagram at 200° and 2 hours

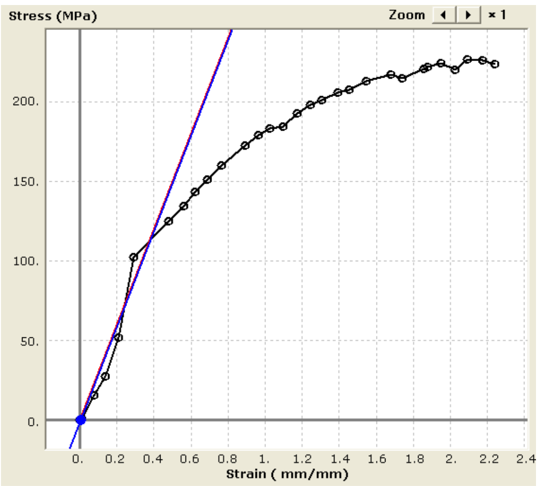

Fig. 3 (b) Stress strain diagram at 150° and 4 hours

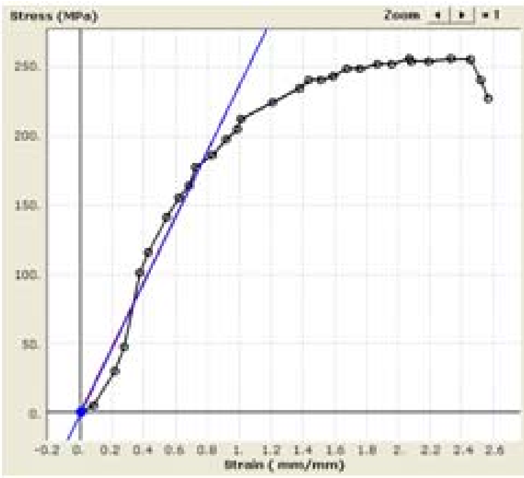

Fig. 4 (b) Stress strain diagram at 200° and 4 hours

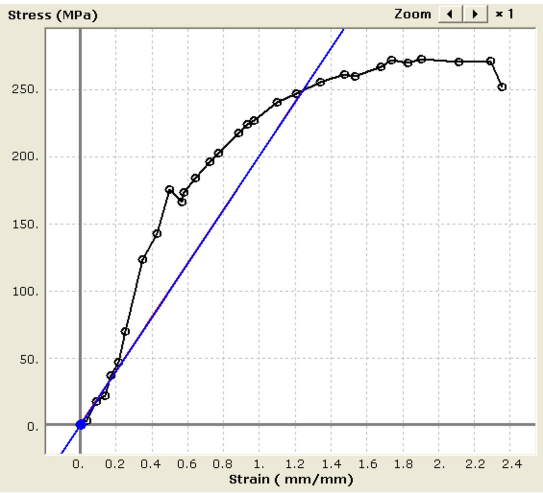

Fig. 4 (b) Stress strain diagram at 200° and 6 hours

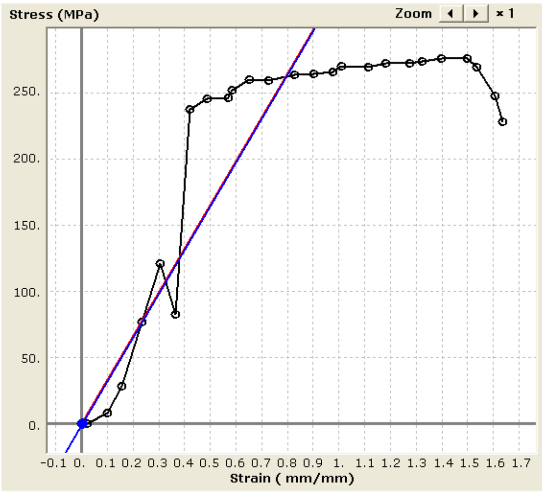

Fig. 5 (c) Stress strain diagram at 230° and 6 hours

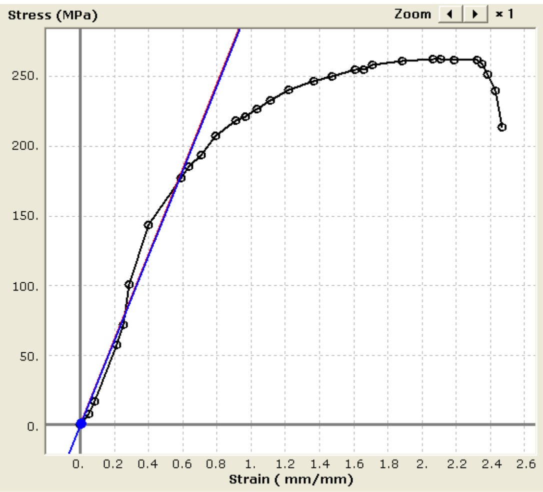

Fig. 5 (a) Stress strain diagram at 230° and 2 hours

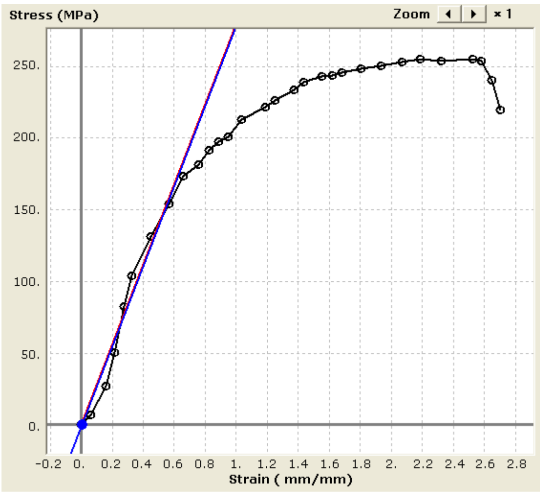

Fig. 6 (a) Stress strain diagram at 280° and 2 hours

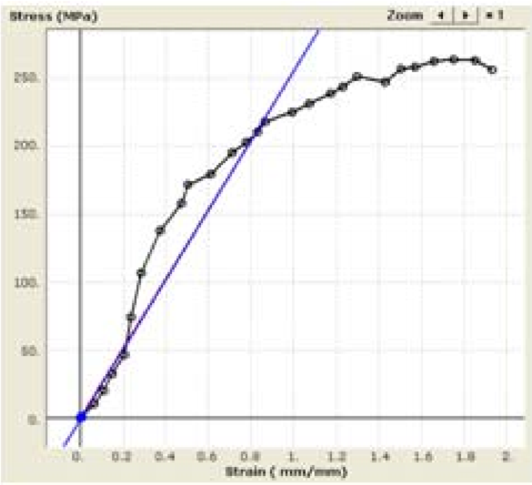

Fig. 5 (b) Stress strain diagram at 230° and 4 hours

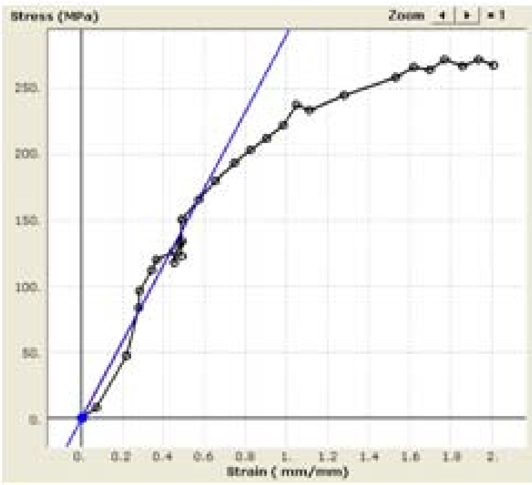

Fig. 6 (b) Stress strain diagram at 280° and 4hours

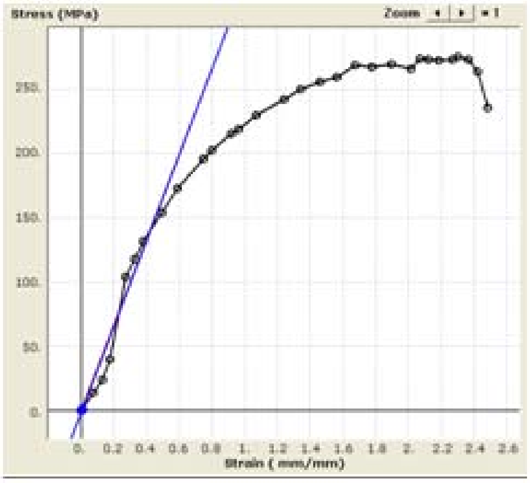

Fig. 6 (c) Stress strain diagram at 280° and 6 hours

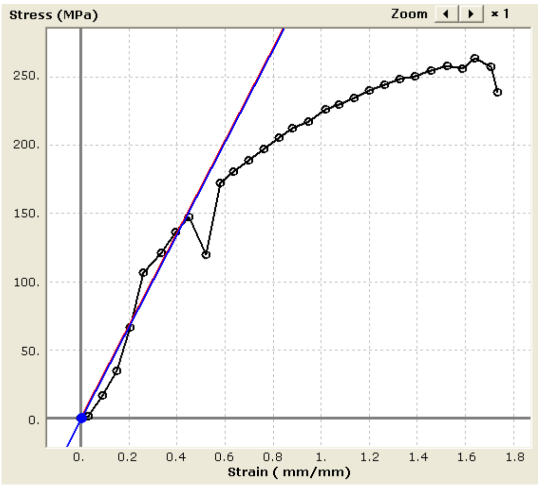

Fig. 7 (a) Stress strain diagram at 310° and 2 hours

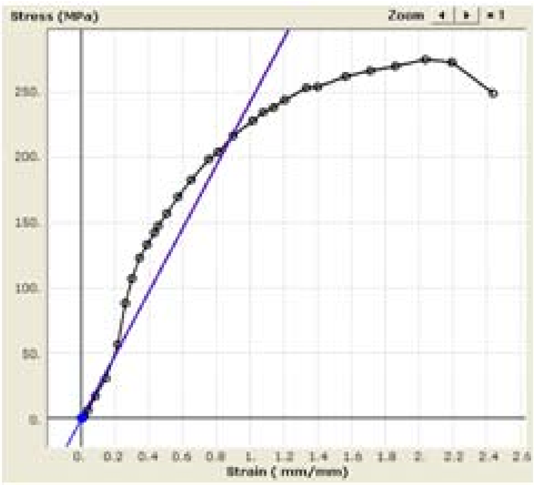

Fig. 7 (b) Stress strain diagram at 310° and 4 hours

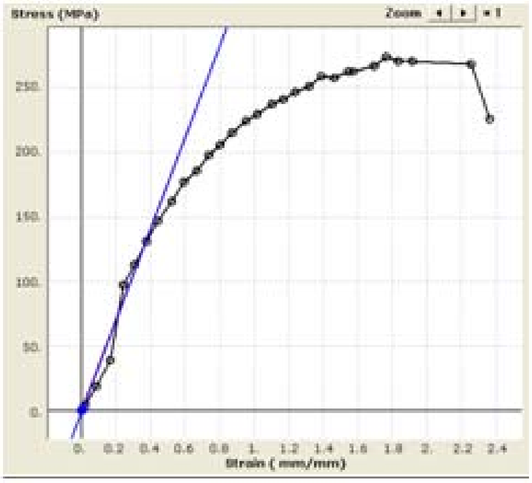

Fig. 7 (c) Stress strain diagram at 310° and 6 hours

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