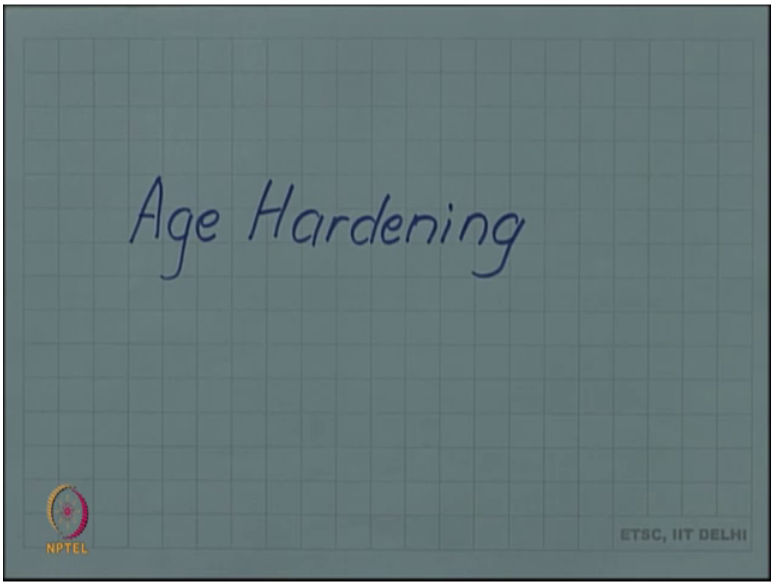
Introduction to Materials Science and Engineering
Prof. Rajesh Prasad
Department of Applied Mechanics
Indian Institute of Technology, Delhi

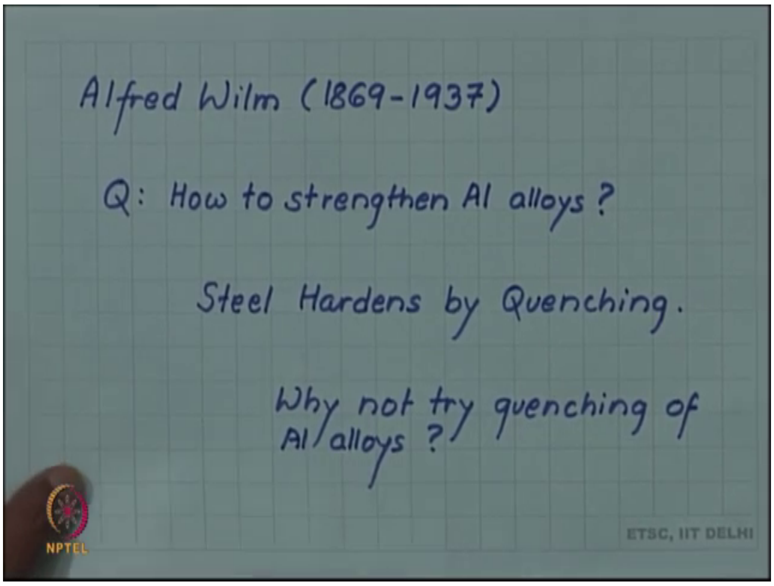
Lecture – 123
Age hardening I

(Refer Slide Time: 00:06)



One very interesting hardening mechanism originally discovered in aluminium alloys is Age hardening.

(Refer Slide Time: 00:22)

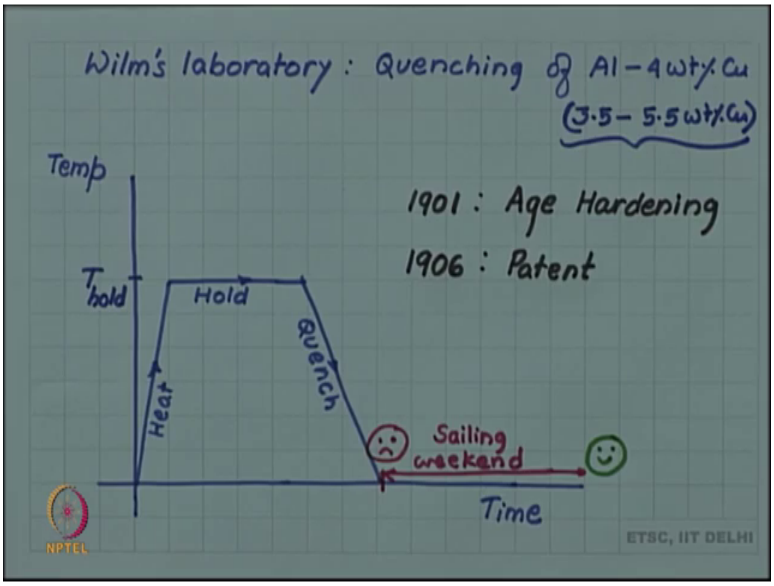


Let us discuss this process. The process started in the laboratory of Alfred Wilm who was working on how to strengthen aluminium alloys. So, he was trying to generate new generation new generation of aluminium alloys and he wanted to have a strong aluminium alloys; aluminium alloys were not fully developed at that time and this was the initial days of research.

So, then he had the background from steel that steel hardens by quenching. So, we have seen that that is steel if taken to austenite phase field and then quenched rapidly enough to miss the nose of the TTT curve, it hardens because it forms a very hard and brittle Martensite.

So, a steel hardens by quenching. So, his natural curiosity or natural query was that can I harden aluminium alloys also by quenching? Will quenching work for aluminium alloys? So, he developed a program of quenching aluminium alloys in his laboratory.

(Refer Slide Time: 01:30)



So, let us visit Wilm's laboratory and look at his experiments. So, as you know temperature and time graph can be made for any heat treatment process. So, he planned to heat the aluminium alloy, hold it and then quench it and after quenching, measure the hardness and the expectation was it like a steel may be the hardness of aluminium alloy also after quenching will increase. So, this is the temperature for holding.

So, he made a range of aluminium alloy in particular aluminium 4 weight percent copper, alloy. The copper percentage is actually he tried from anywhere from 3.5 to 5.5 weight percent copper. So, he made several alloys and then he attempted this heat treatment; heat, hold and quench and then measure the hardness. However, initially he had no success. He heated the sample, held it for a sufficiently long time and quenched it, hardness did not increase. In fact, in some cases, it depressingly decreased; the hardness after quench was even less than the initial hardness he started with. So, the process was not being successful.

But he had he thought about it and he had he was a determined scientist, he had several variables in his hand. At what temperature do you hold and at what rate do you quench? We know from this steel example that if we if we do not go to the austenite temperature, in the temperature range in which austenite phase is stable then and quench it below the eutec, if we take it only below the eutectoid temperature and then quench, it will not it is not going to have any effect, you will not have austenite to begin with and there will be no martensite forming.

So, thus if you want to form martensite, you have to heat it above austenite temperature. So, is this whole temperature important? So, he varied the whole temperature. Similarly again in austenite you find that unless and until austenite is quenched rapidly enough to miss the nose of the TTT curve, martensite will not be produced. So, the quenching rate should be sufficiently fast. So, he varied the rate. With all these experimental variation and of course, he had variation of alloy content also, but none of these variations none of these runs gave him any success. So, in the end there was no increase in hardness and he was not a very happy person no hardness increase.

In one on a on a Saturday morning, he decided to run the experiment again with some new variables and he ran one set of experiment on this Saturday morning, but outdoor he found a beautiful sunshine and he was lover of sailing. So, he decided; he heated quench held and quenched, but before measuring the hardness he decided to go out for sailing have a nice sailing weekend.

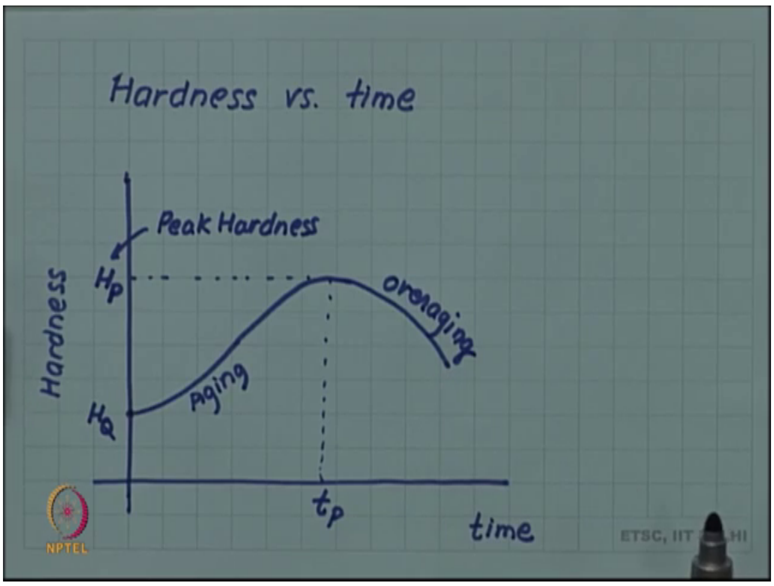
So, he leaves for the weekend; he does not measure the hardness of the quenched specimen goes for sailing and comes back on Monday morning to resume his experiment and when he resumes when he repeats his experiment, when he measures the hardness of the specimens which were quenched on Saturday, but hardness was not measured and the he is measuring the hardness on Monday he finds an increase in hardness, hardness has actually increased. So, he first of all he did not believed himself and worried how the hardness has increased? It has not been increasing for so long.

So, he wondered about this and tried to repeat the experiment again. He freshly quenched the same specimen under same condition again on Monday and measured the hardness there was no increase in hardness. Then it struck him. Is it because is it the weekend effect? Is it because he quenched the specimen on Saturday and is measuring the hardness on Monday that if he is allowing this period of weekend, the sailing weekend that hardness is increasing. So, he did again a control experiment where he quenched and deliberately waited long enough time to measure the hardness and he found that yes, hardness is increasing simply because of waiting.

So, finally, his research was successful, he found a way of increasing the hardness. Hardness does not increase simply on quenching, but quenching and waiting that is as the time passes hardness seems to increase. He did not have an explanation but experimentally he could prove that hardness is increasing as a function of time.

So, this was in 1901, the discovery was in 1901 and he called the process age hardening, he gave the name age hardening, but simply by aging, simply by waiting hardness is increasing and in 1906, he patented the alloy and the process.

(Refer Slide Time: 08:27)

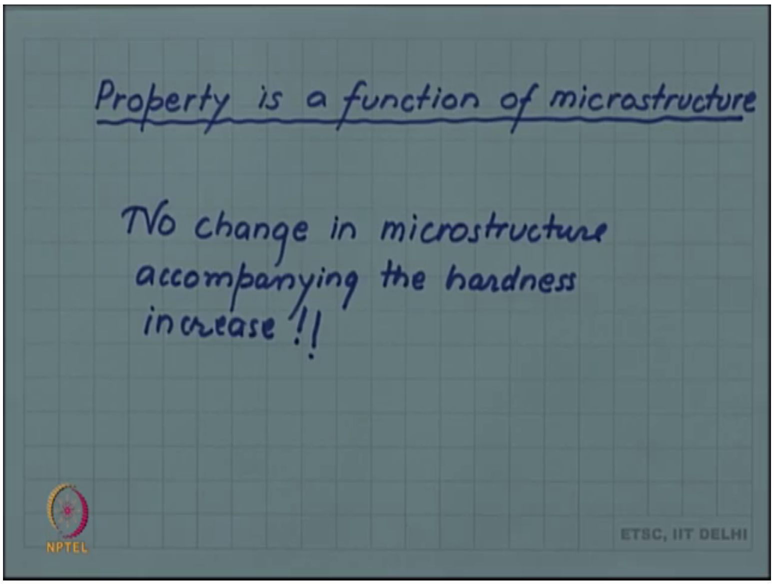


So, let us look at what he found on aging or how does the hardness change as a function of time. So, after quenching there is a hardness value and let us call that H Q hardness in the quenched state and then as time passes the hardness starts increasing and starts going up but then at some point it reaches a peak and then decreases.

Let us call this hardness the peak hardness. So in fact, there are two surprises; why the hardness increases as a function of time and then why it is subsequently it starts decreasing. So, this is this point is called peak. So, H P is the peak hardness and the time corresponding to the peak hardness is called that t p. So, this part of the curve is called aging and beyond peak we call it over aging.

So, I sometime like asking questions to students that why does hardness decrease after attaining its peak hardness during over aging. What is the reason for this decrease? I once got a very interesting answer that since by definition the peak hardness is the maximum hardness, hardness has to decrease after the peak. Well, let us try to see what really is the reason for hardness decrease.

(Refer Slide Time: 10:53)



So, first of all property is a function of microstructure. This is our main theme in the material science course and we have seen this very nicely in particularly in the micro microstructure and property of steels, we saw that in the same steel of 0.8 percent carbon, for example, we can get hardness values by the order of in the range of a factor of 4, we can get a hardness of 15 as rock well or a hardness of 65 rock well simply by controlling the microstructure. So, microstructure is an important determinant of the property in the steel of same composition.

So, here also and Wilm was a good metallurgist and he knew his subject. So, he tried to study the microstructure of his aluminium alloy in which he was seeing hardness increase. Surprisingly, he got what another surprise that there was no change no change in microstructure no change in microstructure accompanying the hardness increase. So, overall the process was very intriguing. Initially the hardness is increasing, then the hardness is in decreasing and you are not finding any corresponding change in the microstructure. So, what is the reason? What is the reason for all this phenomenon? So, we will look at it in detail in the next video.