Steel Quality Role of Secondary Refining and Continuous Casting
Dr. Santanu Kr Ray
Department of Mechanical Engineering
Indian Institute of Technology, Madras

Module – 07
Lecture – 38
Effect of Cast Grain Size

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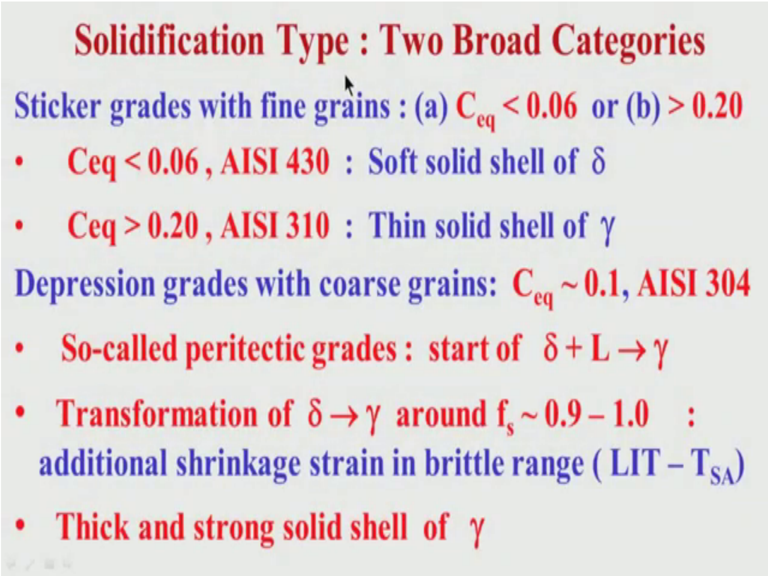

Like solidification there are two broad categories, we call it some grades we are call it they are sticker grades; that means, tendency for sticking is the high and as I have told you since they are sticking towards the mould. So, the heat transfer is relatively high; that means, the you know dendrites will be relatively finer. So, the grains are relatively finer. So, what is the chemistry ranges? For carbon equivalent less than 0.06, carbon equivalent has to be less than that or it has to be more than 0.2. In these chemistry regions we have sticking tendency and fine grains consequence.

So, for carbon equivalent less than 06 or 4 say four thirty as I have mentioned explained for the standard steel, we have soft solid shell of delta. Since we have delta ferrite solidification and even after solidification also we have delta for certain temperature, we know the delta has relatively less high temperatures strain compared to austenite. So, it is soft. Now when carbon equivalent is more than 0.2 this particular region, or aisi three ten one popular stainless steel grade we have thin solid shell of gamma. We have gamma the austenite, but the shell is very thin because of high incidence of micro segregation in austenitic solidification.

So, either for very low carbon or low nickel equivalent and chromium equivalent we have a soft shell or for high carbon equivalent or threatened we have a thin shell. So, in either case will be sticking tendency and fine grains. Now I have mentioned what are the depression grades which chemistry is going to depression. So, depression grades and I have also mentioned depression grade means, there is a formation of the air gap on the surface of the solution so that heat transfer comes down. So, the grains coarse grains coarse dendrites become more coarse.

So, what are the chemistry ranges where the carbon equivalent is around 0.1, for low alloy steel for plane carbon steels or for stainless steels 304. So, these chemistries are prone to the depression and coarse grains why this is happening? Because the so called peritectic grades they start off; that means, near the start off this peritectic reaction delta plus liquid equal to austenite. They call they are called peritectic grades, but the chemistries near the beginning of this peritectic chemistry in around one or around 0.55 nickel equivalent by chromium equivalent. So, they are the start off the peritectic chemistry peritectic yeah.

So, what is happening here one along with that this transformation is delta to gamma, I have mentioned this is around the most you know little temperature region area solid fraction 0.9 to 1. So, additional shrinkage strain in brittle range so, this shrinkage from this transformation is adding to normal shrinkage in this brittle your brittle range, between lit liquid impenetrable temperature and actual solidus. Lit corresponds to solid fraction of 0.9 actual solidus corresponds to a solid fraction of one.

So, here we have thick and strong solid shell of austenite at the end of the solidification it is already austenite. So, we are thick because micro segregation less because you know initial solidification was through delta. So, relatively thick solid shell mushy zone is thin, and strong solid shell because it was austenite. So, there are two broad categories of solidification characteristics and cost structure, depending on the chemistry of the particular alloy this were to keep in mind.

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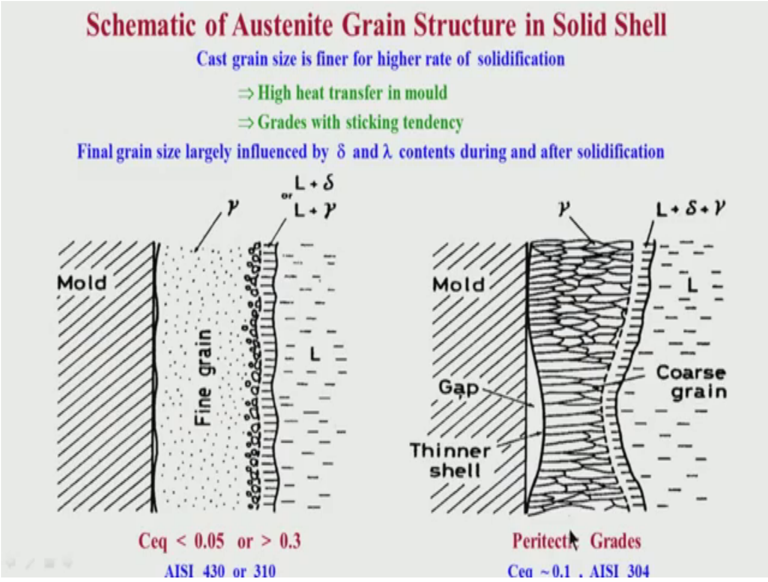

So, the same thing and try to explain here schematically to the austenitic grain structure in solid shell. You know after solidification beyond certain temperature; that means, when we are cooling to lower temperature finally, all grades will become austenite let us speak of the chemistry. But solidification modes some where it is delta some where it is delta plus gamma, some where it is only gamma austenite. So, certain chemistry range as I have told you will give you depression tendency, sudden you know chemistry will give you sticking tendency, and bulging tendency below the mold and sticking tendency inside the mold.

So, when we have a sticking tendency what do you have? We have fine grains solidification is either through liquid plus delta or through liquid plus gamma; that means, either very low carbon equivalent or very high carbon equivalent, either peritectic four thirty or austenitic three ten. So, these are the chemistries where you have this type of structures because of sticking characteristics and in the peritectic grades, so called peritectic grades where you have carbon equivalent of say 0.1 or AISI 304 standard steel.

So, what is happening here initially liquid to delta and then it goes to delta liquid plus delta to gamma; that means, gamma transformation is taking place towards the end of the solidification. So, this creates depression tendency, depression means there will be air gap between the mold and the solid shell. So, the solid shell will become thin because this hotspot formation this is the hot spot formation. So, heat transfer is getting affected getting lower. So, we have coarse grains; though it is relatively magnified you do not have so much of course, again this has been done just to distinguish between the two characteristics, but nevertheless I will show it to you what are the grain sizes cast grain sizes what you get during casting of different carbon chemistries.

But what is important here to see that for carbon equivalent very low less than 05 or high more than say 0.25 or 0.3, you have relatively fine grain cast structure. Similar is the case for peritectic 430 or totally austenite 310 standard steel. But for the so called peritectic grades; that means, chemistry near the start of the peritectic chemistry; that means, around 0.1 or around 0.55 nickel equivalent by chromium equivalent for standard steels, you have depressions because of that there is a gap formation there is a we call it hot spot formation because of that heat transfer is affected becomes low, and we have coarse grain structure.

So, cast grain is finer by higher rate of solidification if you have higher rate of solidification cast grain will you finer. So, this is dictated by two things one is the heat transfer in the mould; that means, grades with sticking tendency you have finer grains and finer grain is largely influenced by delta gamma context during and after solidification. Because if you have delta during casting and also at temperature lower than the casting; that means, for very low carbon equivalent or say 430 by the delta to gamma transformation is taking place quite at quite lower temperature, even after solidification. So, delta is you know present for quite some time for quite a big temperature region. So, there is a possibility of grain coarsening of delta.

So, there we have to be a bit careful. So, in such cases you know the earlier will be the onset of austenite finer will be the delta grains. So, here the grains are coarser because of heat transfer consideration because the solidification characteristics, here delta to gamma in the solid transformation is important if you can start that delta to gamma transformation at higher temperature just after solidification you do not allow the delta grains to remain at high temperature for sometime question time then you have relatively finer austenite grain size, otherwise relatively finer ferrite and austenite grain size otherwise if you have large austenite grains then you have some difficulty yeah.

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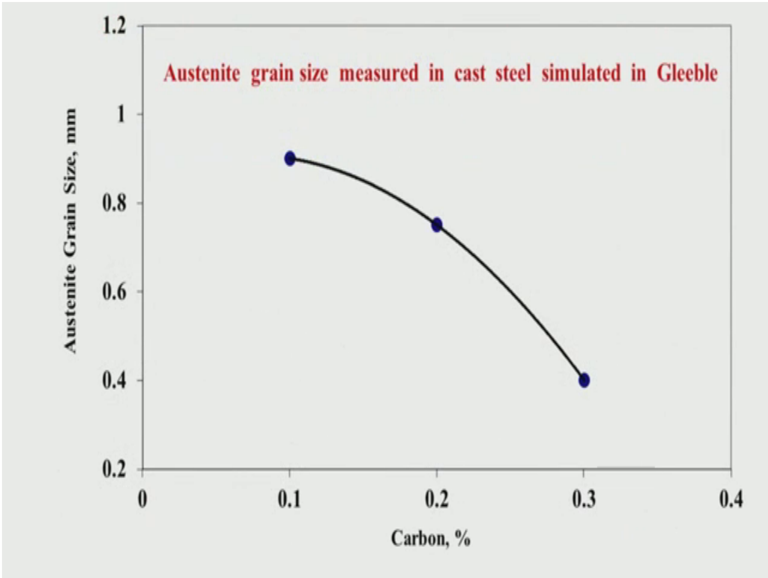

As I was telling you we can measure the austenite grain size in the cast still now how it is done? Say we have we can simulate continuous casting in a machine we called it gleeble is the simulator. So, what we can do is, we can take a solid sample say from you know from the different region of the cast product having different chemistry, and then we can heat it till it goes to the liquid you know region and then you can simulate the continuous casting by cooling it and at a rate which is equivalent to the continuous casting rate cooling rate. So, in the gleeble simulator we can use situation, cooling condition similar to continuous casting and then we can see what are the phases present we can interrupt the cooling at different temperatures and see what are the phases present this is possible, or we can cool it to the room temperature at any rate what we want and we see what was present at any particular temperature.

So, likewise what we have done we have tried to see for different carbon concentration carbon chemistry, what was the austenite grain size in the cast steel, after we have simulated in the gleeble. So, we have found that 0.1 percent carbon as I told you this is so called peritectic chemistry, we have relatively larger grain size this is around say 0.9 millimeter is quite big, and when we come to the say 0.3 percent carbon you see it is a relatively less 0.4. So, it is more than double. So, 0.1 percent carbon as I was showing here peritectic grades means around 0.1 percent carbon the cause cast grain size are relatively larger compared to the cast grain austenite.

So, you can see here actual measurements done during solidification which has been simulated in a gleeble simulator gleeble machine. So, the austenite grain size is quite you know large 11.9 is quite large. This of course, cast grain size and then for around 0.3 percent carbon it is decreasing as you are increasing the carbon as I told you when we are going to say 0.3 percent carbon means you are coming to a this type of situation were sticking tendency is quite high and 0.1 percent carbon is a depression tendency; depression means there is a gap formation on the surface the hot spot formation on the surface you know heat transfer is low because of this and we have relatively coarse grains coarse grain of austenite. For sticking tendency if you have very low or very high carbon say 0.3 percent carbon is it sticking characteristics sticking means there is no air gap formation between no mold and the relatively much less between the mold and the under what is that called solid shell here you see the gap formation is quite large here gap formation is minimum quite low.

So, this possibility of grain coarse grain is quite less here for sticker grades, but for the depression type of grades you have possibility of grade coarse inning. So, you can actually see what are the austenite grain size, when you simulate under gleeble. So, around 0.1 percent carbon it is quite large, 0.3 percent carbon it is quite relatively relatively less 7.4 millimeter and here it is about 0.9 millimeter is quite large size. So, we have tried to explain depending on you know the type of solidification there are two broad categories one is sticker grades; that means, which will have sticking tendency during solidification and the grains will be finer as I have explained. So, two chemistry rangers we have such you know tendency either the carbon equivalent is low less than 06 or carbon equivalent is high more than 0.2, 0.25, 0.3.

So, or even is I 430 is equivalent to very low carbon or three ten which is equivalent to very high carbon equivalent more than 0.5. So, this here you have thin this for high carbon equivalent at 310 because of austenitic totally austenitic solidification, you have thin solid shell of gamma. Because it is thin you know it cannot withstand ferrostatic pressure say is sticking tendency and for low carbon equivalent and low nickel equivalent by chromium equivalent that is 430, you have soft solid shell because it is delta so that also kind of resist ferrostatic pressure strain. So, it is sticking tendency, but when the carbon equivalent is around point one or yeah AISI 304 having a nickel equivalent by chromium equivalent around 0.55 slightly more than 0.55 you have depression. So, you have coarse grains relatively coarse grains.

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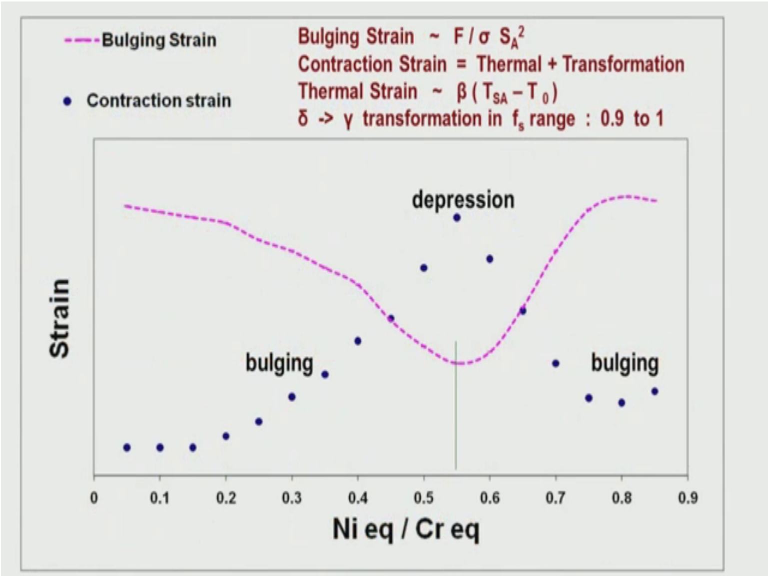

The same thing has been explained pictorially this first for standard steels around 0.55 we have relatively high you know contraction strength. So, you have depression the bulging strain is relatively less and for very low nickel equipment by chromium equivalent where the reverse is two we have bulging sticking and for high nickel equivalent chromium equivalent that is AISI 310 type of grade, we have again bulging.

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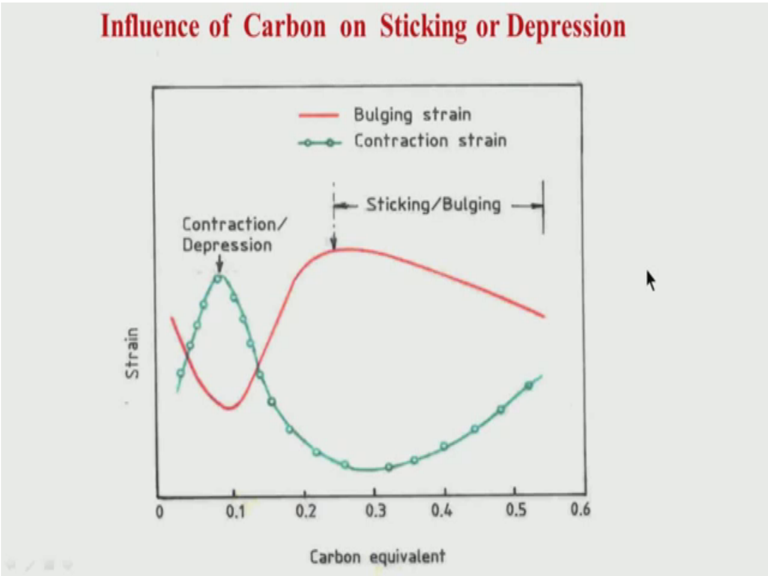

Similar effect for carbon grades you see around 0.1 the strain contractions raise is relatively high. So, we have depression tendency contraction depression tendency and for very low carbon or very high carbon we are sticking and bulging tendency. So, what is important is again I am repeating depending on the chemistry, we have two broad transformation on a on the solidification behavior either sticking or depression. And as I have told you depending on this inherent characteristic we can decide what through the casting parameters because it is a sticking grade we have to take care of the sticking as much as possible.

So, it is intrinsic characteristics by continuous casting process we have to take care of this problem on this issue. So, if it is a if the characteristic is other type is a sticking type then we have to take care of it by controlling the you know friction if you have sticking means what? Let us try to see what is going to happen if you are sticking yeah if you have a sticking tendency; that means, this solid shade is going to try to touch the mold surface; that means, though in between you have a thin shell off thin layer of you know what is that called powder which is molten; that means, slag more slag. So, the mold slag characteristic is is to be such that this friction between the mold and the solid shell is relatively less because sticking tendency will there will be more friction the friction will be relatively high. So, the characteristic of the mold slag has to be such that this high friction can be taken care of. Here in politically grades friction is not an issue here the issue is gap formation.

So, gas formation means the heat transfer is coming down. So, the powder characteristic and the slag characteristics will be such that this heat transfer has to be taken care of. So, it is the you know because of sticking the friction has to be taken care off in mold, and here because of the depression tendency this heat transfer has to be taken care off in the mold. So, as I have told you depending on the type of solidification characteristic, you must use different mould powder having different characteristic. Because here we have to take care of the friction, friction is relatively high we should not allow too much of friction otherwise there will be sticking break out stickers break out here it is just the reverse there is no sticking there is a air gap formation. So, heat transfer is getting affected; that means, too much of depression.

So, we have to control the depression we have to see that the uniformity of heat transfer is there throughout the periphery of the mold that is what is important here. Here what happens is at certain locations heat transfer gets affected. So, more powder to be such that it gives a mold slag which can control this heat transfer uniformly. So, here the heat transfer control is the main issue for peritectic grades where you have lot of the depression our purpose is to control the depression. So, through controlling the heat transfer or for sticker grades, it will try to stick more towards the mold friction between mold and a solid shell is the issue. So, you have to reduce the friction between mold and solid shell.

So, the powder has to be such that the mold slag should have such characteristics that it can resist the friction it can lower the friction, between the mold and the solid shell. So, here friction is the issue we have to take care of that here heat transferred is the issue which we have to take care of by using proper mold slag. So, as I was telling you depending on the characteristic of the alloy we have to use different casting parameters; we have to use different casting powder casting powder is one then the I have told you about the you know mold oscillation, mold oscillation also should be different because what is the purpose of mold oscillation, purpose of mold oscillation is to avoid sticking to give duplication.

So, since the sticking tendency is high here we should have you know mold oscillation of certain characteristics where the cycle of you know the frequency of the oscillation should be low, and the amplitude should be high. Here for you know peritectic grades which have depression tendency it is just the reverse. Here the surface as I told you the oscillation depth is relatively more in peritectic grades. So, our purpose is to control depression and oscillation depth of oscillation marks. So, here what we have to do we have to use high frequency of oscillation with low amplitude a mold oscillation.

So, the frequency is more here oscillation is less here frequency is less here oscillation is more here. So, the powder is different oscillation characteristics are different. So, we have to keep in mind depending on the characteristics solidification characteristic or type of behavior solidification behavior whether it is you know sticking type or depression type we can design the casting parameters accordingly to get better surface quality better internal quality of cast structure. Similarly you know as I have told you for this type of grades normally you have to use relatively mold of secondary cooling intensity of secondary cooling, for such type of grades we do not want high rate of transfer heat transfer not only in mold even below the mold. So, the secondary cooling also is relatively less. So, depending on the grades we have to design the parameters casting parameters accordingly.

Thank you very much.