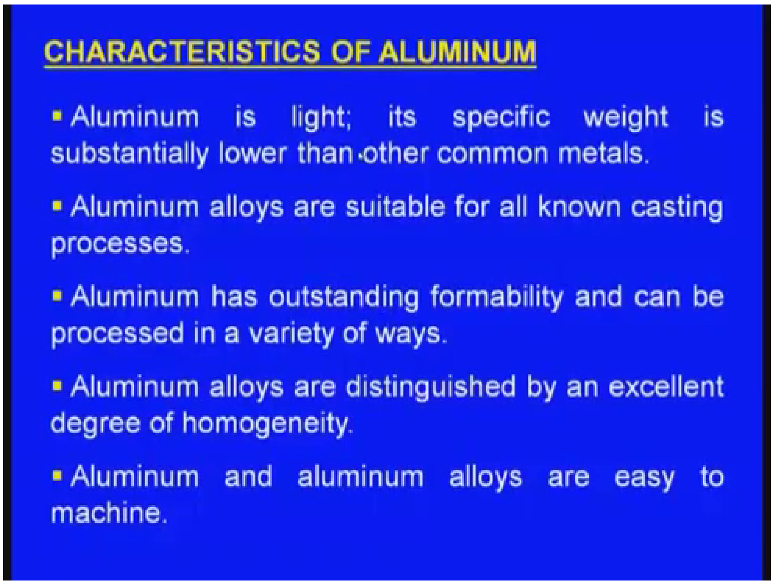
Metal Casting
Dr. D. B. Karunakar
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Module - 04
Common Cast Alloys
Lecture - 02
Aluminium And Magnesium Cast Alloys

Good morning friends. In the previous lecture we have learnt about cast irons and cast steels. Now in this lecture let us learn about Aluminum and Magnesium Cast Alloys. First we will see the aluminum cast alloys. Next we will see the magnesium cast alloys aluminum cast alloys first let us see the characteristics of aluminum.

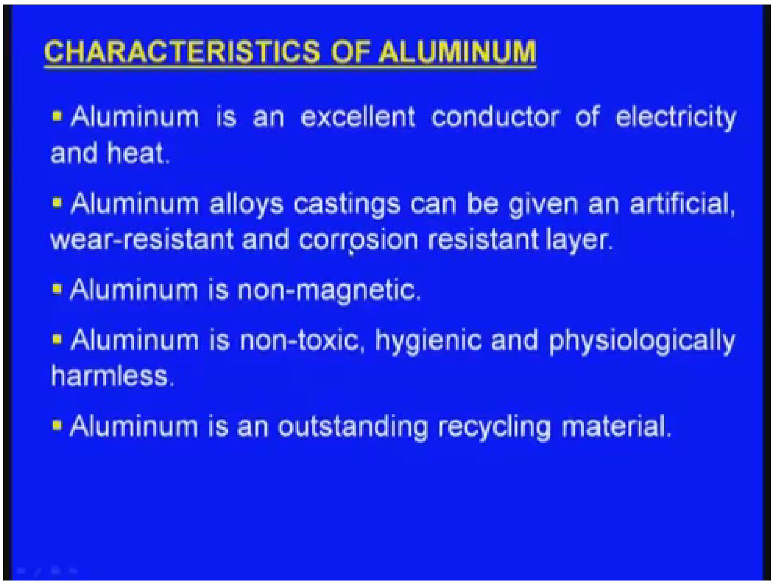
(Refer Slide Time: 00:47)



Aluminum is light in weight it is specific weight is substantially lower than other common metals, aluminum alloys are suitable for all known casting process means there are difference different casting process are there sand casting, die casting, investment casting, aluminum can be used for all the casting process. Aluminum has outstanding formability and can be processed in variety of ways. Next aluminum alloys are distinguished by an excellent degree of homogeneity means uniform composition everywhere.

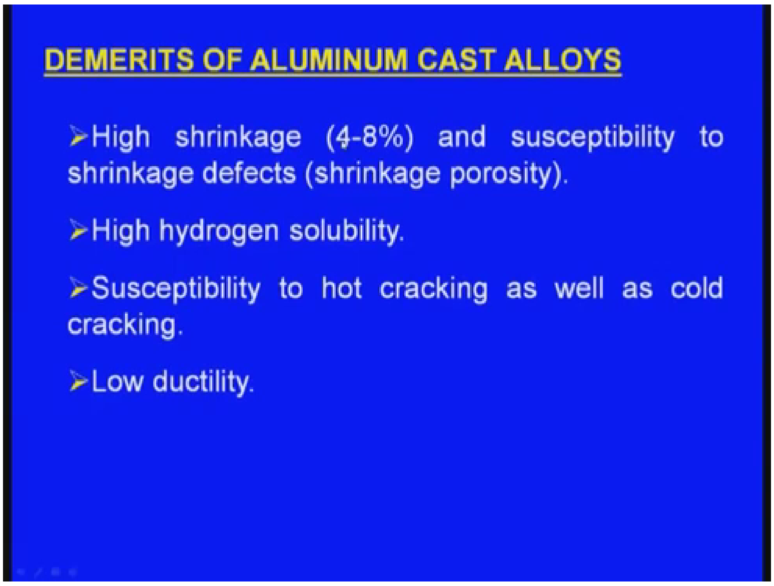
Aluminum and aluminum alloys are easy to machine there machinability is good.

(Refer Slide Time: 01:31)



Next one, aluminum is an excellent conductor of electricity and heat; aluminum alloys castings can be given an artificial wear resistant and corrosion resistant layer. So, that is easy in the case of the aluminum castings. Next one aluminum is nonmagnetic aluminum is nontoxic hygienic and physiologically harmless aluminum is an outstanding recyclic material. So, these are all the advantages in fact characteristics of aluminum.

(Refer Slide Time: 02:08)

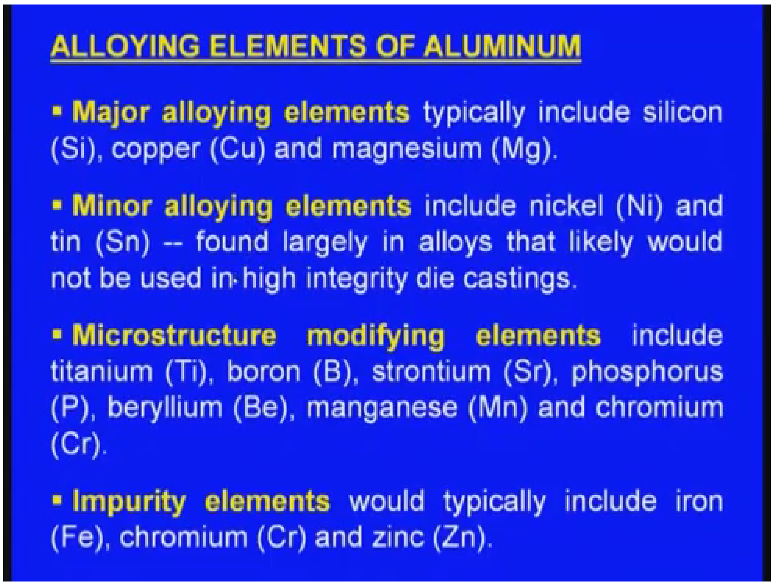


Now, these are the demerits of aluminum cast alloys high shrinkage the shrinkage will be nearly 4 to 8 percent and it is highly susceptible to shrinkage defects and all shrinkage porosity.

Now, it has the highest hydrogen what say absorbed beauty it absorbs hydrogen rapidly, now susceptibility to hot cracking as well as cold cracking during solidification this hot cracking develops. Now there is another cold cracking cold cracking means during solidification it absorbs hydrogen and this hydrogen will be atomic hydrogen because of the high temperature. Now during solidification this atomic hydrogen will become molecular hydrogen and as the solidification is progressing, as inter atomic spaces are reducing, the molecular hydrogen cannot be accommodated inside thus it what say exerts pressure inside and that is how it results in cracking.

So, this is the cold cracking. So, it has the susceptibility to hot cracking as well as cold cracking and it has low ductility.

(Refer Slide Time: 03:15)



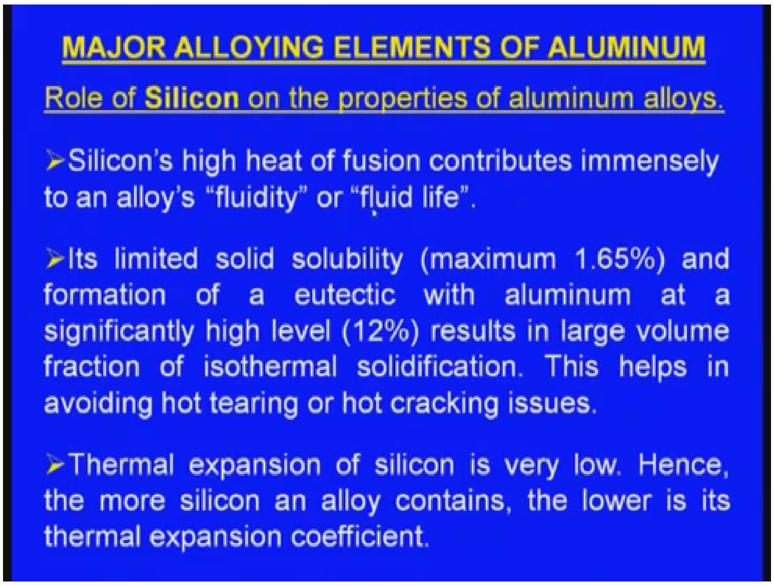
Now, let us see that is why the pure aluminum may not be suitable for the casting purposes, but we can alloy it we can add different alloying elements and we can make it useful for our what say casting purposes, now when we say alloying elements we can see there are 4 types of additives are there first one is the major alloying elements typically include silicon copper and magnesium.

So, these are the major alloying elements in aluminum next one there will be minor alloying elements. So, these are nickel tin right. So, these are found largely in alloys that are likely to that likely would not be high in integrated die castings, next one apart from the major alloying elements and minor alloying elements there will be micro structure modifying elements; means what is the purpose we are what say modifying the micro structure. So, these include titanium, boron, strontium, phosphorous, beryllium, manganese and chromium.

So, we add these elements extremely small amount. So, that the composition is almost unaltered, but it will be changing the microstructure, next one there will be impurity elements what are these impurity elements means these are the elements coming in through what say through the aluminum without our knowledge and without our intension. So, such elements are called as the impurity elements or all they are also known as the residual elements. So, these typically include iron chromium and zinc.

So, iron is the most common what say impurity element in the aluminum, next is the chromium and also the zinc. So, these are the 4 types of the additives that we can see in the aluminum castings first we will see the major alloying elements, next we will see the minor alloying elements, next micro structure a modifying elements, next we will see the effects of the impurity elements first we will see the major alloying elements.

(Refer Slide Time: 05:19)



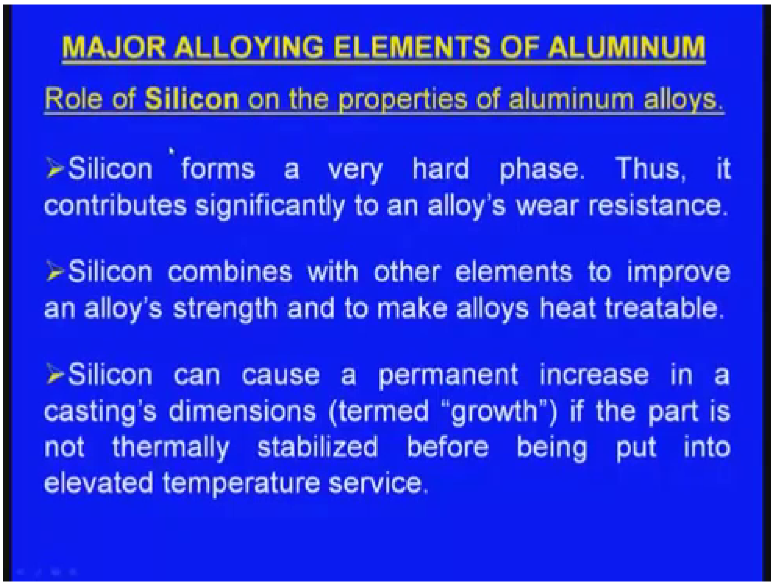
Now, among the what is a major alloying elements first one is the silicon.

Silicon is the what say most what say used alloying element it is the number one major alloying elements in the aluminum castings, now what is it is role silicon high heat of fusion contributes immensely to alloys fluidity or fluid life. Now it has got the high heat of fusion means what happens during solidification during the face change it liberates lot of heat, now because it is liberating lot of heat what happens it is what say temperature of the alloy will be increasing that is how the fluidity will be increasing.

As the temperature is increasing fluidity will be increasing. So, silicon contributes to the fluidity of the aluminum alloy, next one it is limited solid solubility maximum will be 1.6 5 and formation of a eutectic with aluminum at a significantly high level 12 percent results in large volume fraction of isothermal solidification. This helps in avoiding hot tearing or hot cracking issues. So, silicon is not only increasing the fluidity, but it is these also helping us to what say prevent the hot cracking.

Next one thermal expansion of silicon is very low hence the more silicon an alloy contains the lower is it is thermal expansion coefficient most of the times what happens as the what say we pour the molten metal what happens if they what say thermal expansion of the alloy is high what happens the mold cavity may break because of the high thermal what say expansion of the alloy, but because of the silicon the thermal expansion will be minimum that is how there would not be any what say mold damage.

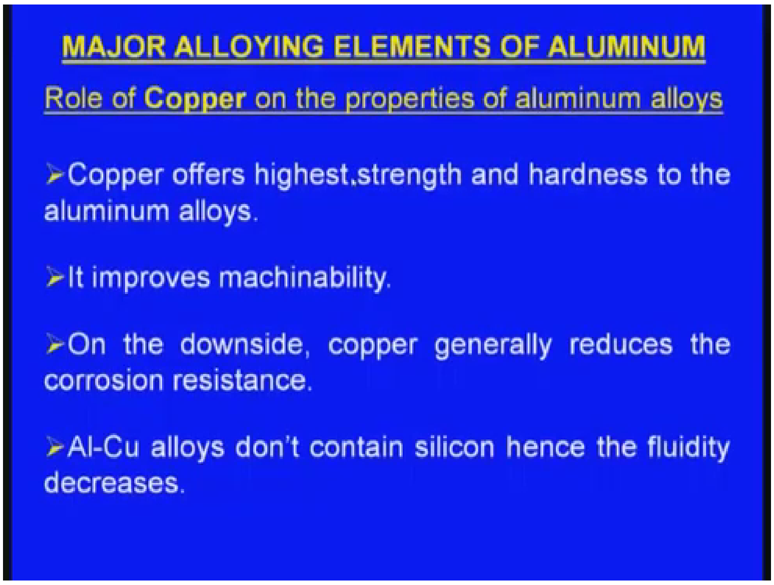
(Refer Slide Time: 07:14)



Next one there are other roles made by the silicon; silicon forms a very hard phase if we see the silicon it is a very hard material thus it contributes significantly to an alloys alloys wear resistance, because it is very hard when we mix this hard silicon in the aluminum melt what happens it improves the wear resistance of the alloy, next one silicon combines with other elements to improve an alloys strength and make alloys heat heat treatable, next one silicon can cause a permanent increase in a castings dimensions termed growth if the part is not thermally stabilized before being put into elevated temperature service.

Next one the other what say major alloying element of aluminum is the copper.

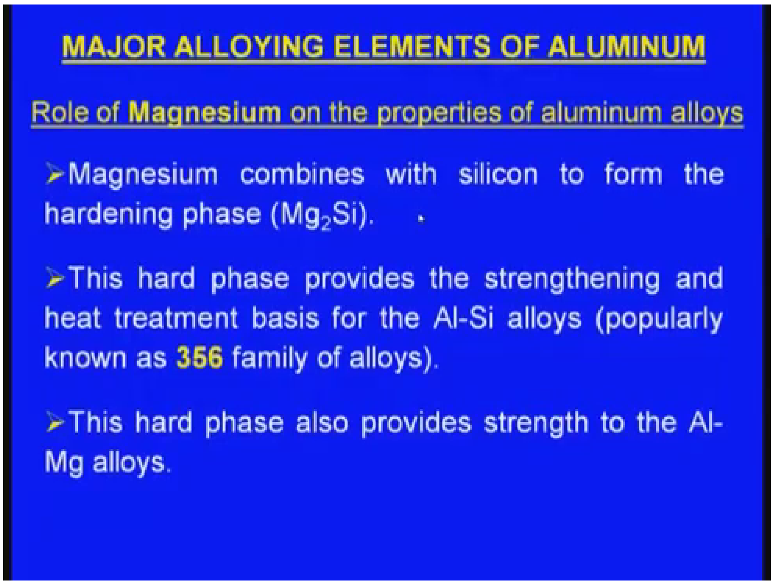
(Refer Slide Time: 08:09)



Now, what is the role of copper on the properties of aluminum alloys copper offers highest strength and hardness to the aluminum alloys. So, the most commonly used what say alloy is the duralumin it contains copper why the duralumin is very hard and strong because it contains copper it improves machinability.

On the down side copper generally reduces the corrosion resistance aluminum copper alloys do not contain silicon hence the fluidity decreases; next one next major alloying element is the magnesium.

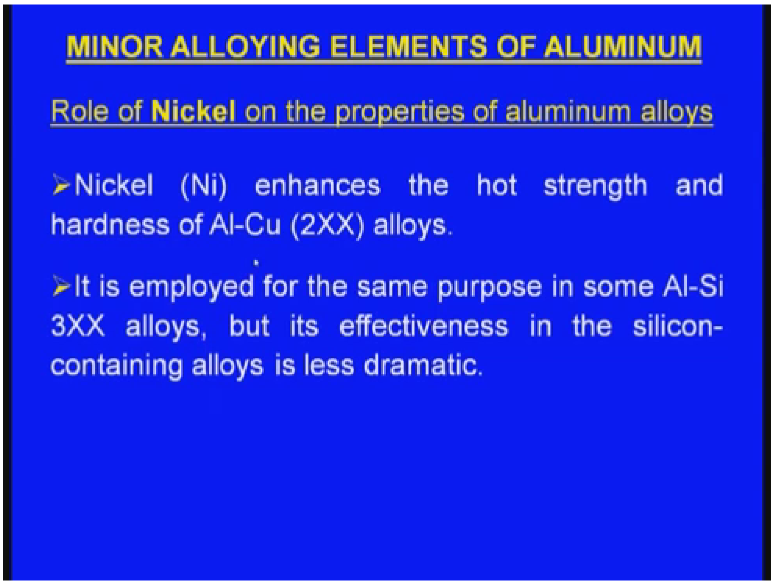
(Refer Slide Time: 08:38)



Now, what is the role of magnesium on the properties of aluminum alloys magnesium combines with silicon to form the hardening phase magnesium silicate you see M g 2 S i. So, this is a very hard phase, because of that what happens the what say alloy what say develops good strength and also wear resistance this hard phase provides strengthening and heat treatment basis for the aluminum silicon alloys popularly known as the 356 family of alloys.

Next one this hard phase also provides strength to the aluminum magnesium alloys. So, magnesium typically it what say forms the hardening phase thus it what say induces strength to the alloy, now we have completed the major alloying elements of the aluminum.

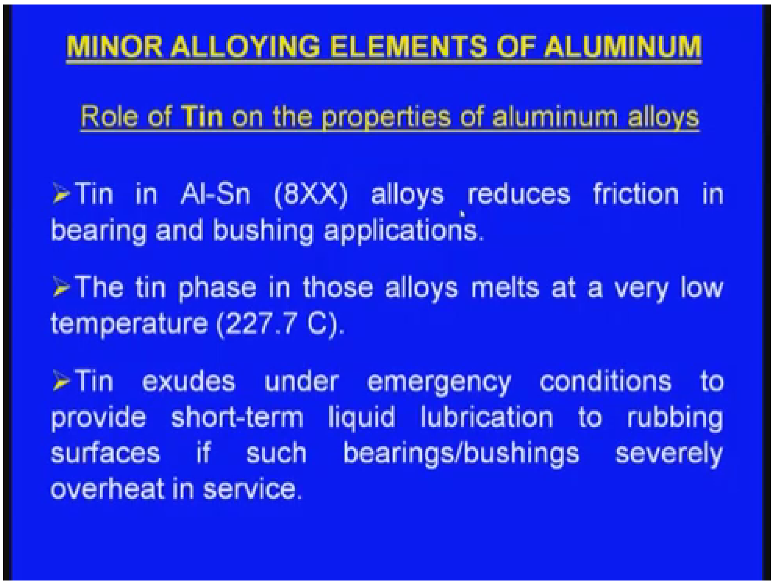
(Refer Slide Time: 09:45)



Next we will see the minor alloying elements, among the minor alloying elements the first minor alloying element is the Nickel; Nickel enhances the hot strength and hardness of aluminum copper alloys it is employed for the same purpose in some aluminum silicon 3XX alloys, but it is effectiveness in the silicon containing alloys is less dramatic.

Next one another minor alloying element is the tin what is it is role tin in aluminum tin alloys.

(Refer Slide Time: 10:04)

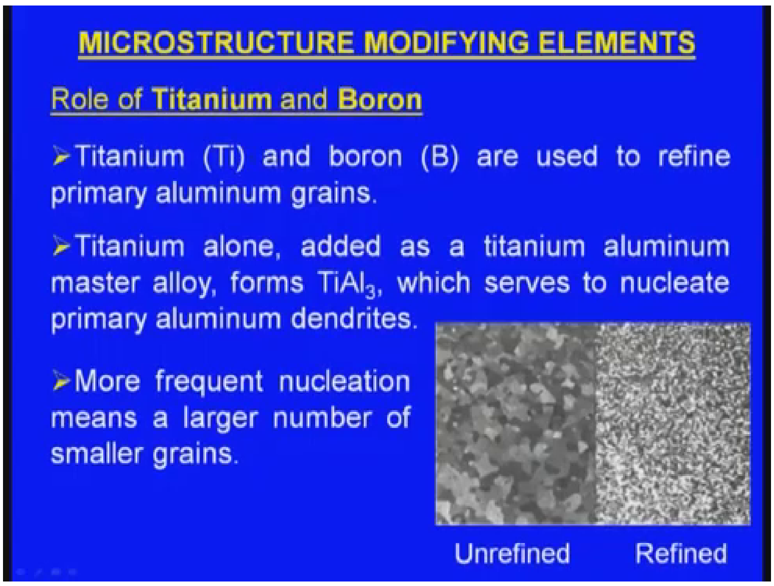


So, these are popularly known as 8XX series we will see later, now the what say this tin reduces friction right in bearings and bushing applications the tin phase in those alloys melts at a very low temperature at about 200 and 27 degrees. Now then what happens tin exudes under emergency conditions to provide short term liquid lubrication to rubbing surfaces if such bearing bushings severely over heat in service. So, this is the greatest advantage of using in the bearings. So, this tin is used for the bearing the applications in the in the manufacture of the bearings, now what happens in the bearings one part will be rubbing over another part so most of the times we use the lubricants.

Now, fine sometimes this lubricant may be adjusted or there may not be any lubricant what will happen then heat will be developed, now we are the one part will be rubbing over another part what will happen, finally the parts will be damaged severely. At such times what happens this tin exudes under emergency conditions and it will be supplying few drops minor drops of liquid tin at the rubbing surfaces then it causes the lubrication between the rubbing parts.

So, this is the greatest advantage of tin, next one so far we have completed the major alloying elements and the minor alloying elements, next we will see the microstructure modifying elements among the microstructure modifying elements the popular What elements are the titanium and boron and what are their cores titanium and boron are used to refine primary aluminum grains.

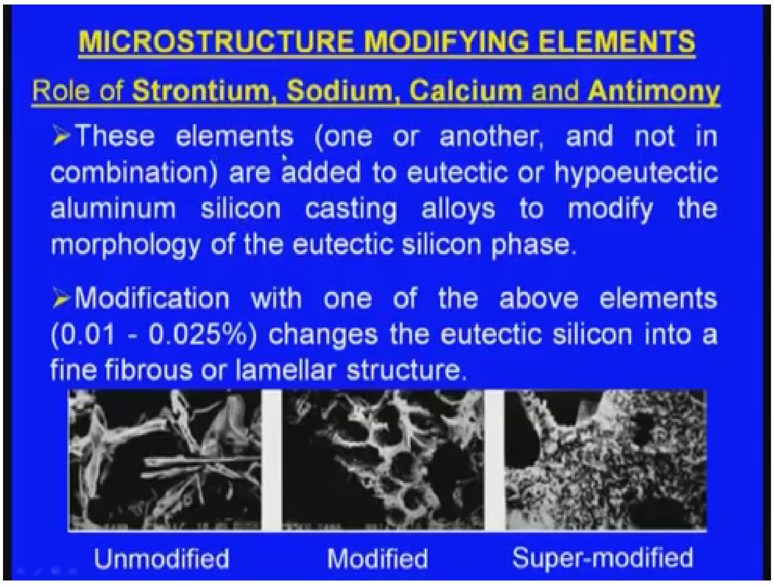
(Refer Slide Time: 11:49)



Initially if we do not use any what say modifier the grain will be very cors, when we use this what say modifiers like titanium and boron we get a very fine what is say grain structure. Titanium alone added as a titanium aluminum master alloy forms T i A l 3 you see which serves to nucleate primary aluminum dendrites more frequent nucleation means large number of smaller grains.

Now, you can we can see here this is the unrefined grain structure and here this is the refined grain structure, this refined grain structure offers us better mechanical properties that is why there is a need to add microstructure modifying elements; next one role of strontium, sodium, calcium, and antimony.

(Refer Slide Time: 12:49)

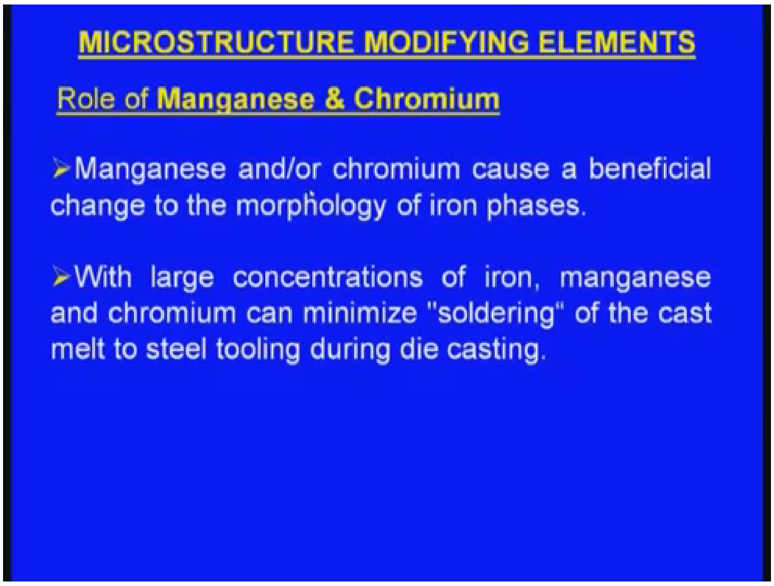


So, these are also they also come under the microstructure modifying elements. So, these elements one or another, but not in combination only one should be used at a time or added to eutectic or hypo eutectic aluminum silicon casting alloys to modify the morphology of the eutectic silicon phase.

Modification with one of the above elements say you see the proportion 0.01 to 0.025 percent extremely small amount changes the eutectic silicon into a fine fibrous or lamellar structure and here this is the unmodified. So, this is modified and this is super modified. So, these what say microstructure modifying elements like strontium sodium calcium and antimony only one at a time, but not in combination helps us to get a better what say microstructure with improved properties.

Next one among the microstructure modifying elements the next what say elements are the manganese and chromium.

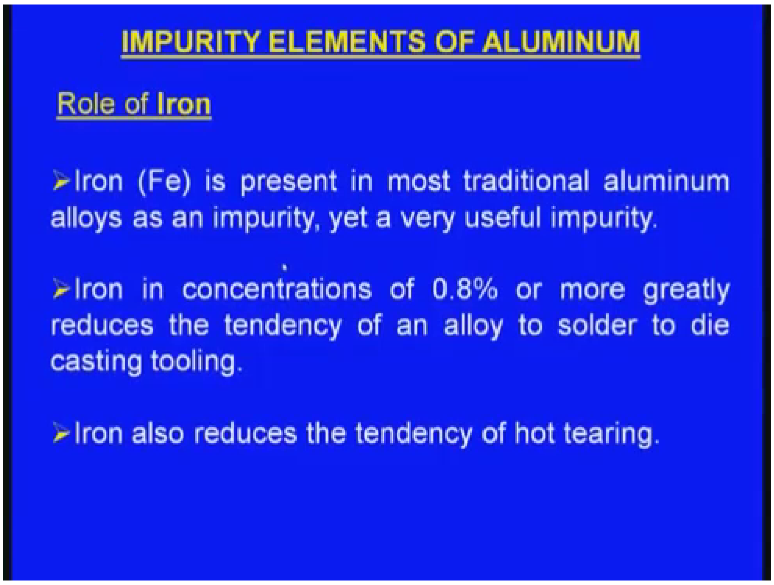
(Refer Slide Time: 13:54)



And what are they roles manganese and or chromium cause a beneficial change to the morphology of iron phases with large concentrations of iron manganese and chromium can minimize shouldering of the cast melt to steel tooling during die casting so in the die casting applications. So, there is a drawback called shouldering means there will be metallic dies will be used. So, the molten metal will be sticking to the metallic dies. So, this is the shouldering.

So, this problem can be minimized when we use these modifying elements like manganese and chromium. Next one the last additives these are the impurity elements these are also known as the residual elements among them the first one is the iron.

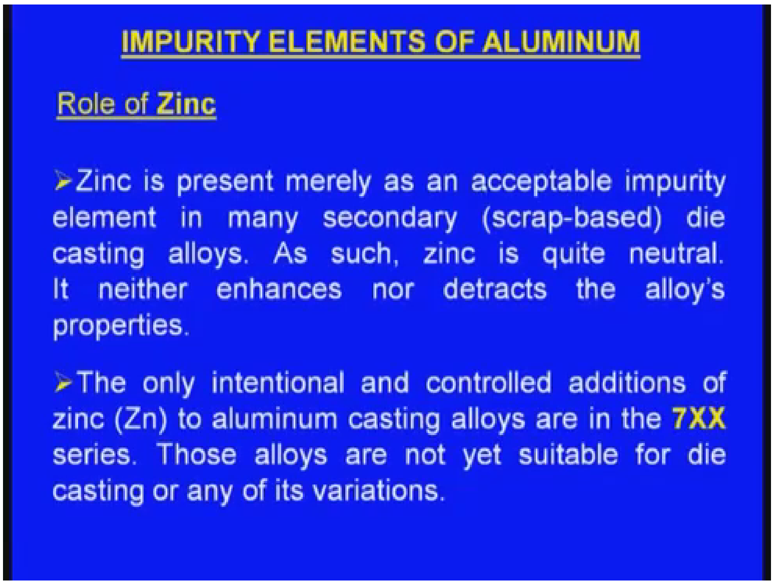
(Refer Slide Time: 14:43)



And what is it is role iron is present in most of the traditional aluminum alloys as an impurity means it comes into the alloy without our knowledge and without our intention yet it is very useful impurity though it is coming into the alloy without our knowledge and without our intention it gives us some benefits.

Iron in the concentrations of say you see the concentration may be 0.08 these the normal composition at the most it will be one percent are more greatly right it reduces the tendency of an alloy to shoulder to the die casting tooling again say there is a or drawback right this shouldering defect can be reduced in the die casting iron also reduces the tendency of hot tearing; so again, hot tearing or the hot cracking another drawback in the aluminum castings. So this aluminum which comes into the alloy as an impurity element or as a residual element minimizes the hot tearing.

(Refer Slide Time: 15:47)



Next one another impurity that is the Zinc; Zinc is present nearly as an acceptable impurity element in many secondary scrap based die casting alloys as such zinc is quite neutral it is neither enhance it neither enhances nor detracts the alloys properties the only intentional and controlled additions of zinc to aluminum casting alloys are in the 7 X axis series right. So, these alloys are not yet suitable for the die casting are any of it is variations only in one case that is the 7XX series, we will be seeing these later within few minutes right. So, in those series this is intentionally allowed or intentionally added for obtaining certain properties.

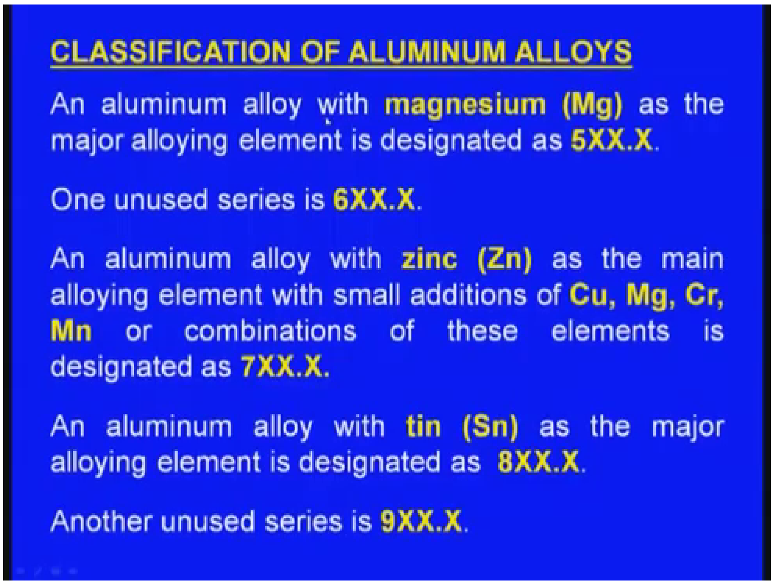
Now, let us see the classification of aluminum casting alloys we have seen the different, what say alloying elements, the major alloying elements, the minor alloying elements, what say microstructure modification elements, and the what say impurities we have seen next are the how these alloy aluminum alloys are classified on what basis.

(Refer Slide Time: 16:51)

Now, this is the classification of the aluminum cast alloys; aluminum cast alloys are grouped based on the major alloying element present in that based on that they are classified. Aluminum greater than 99 percent is designated as 1XX series means here it is the mostly it is the pure aluminum 99 percent aluminum is present, it is mostly the aluminum no other what say element is there no other major alloying element is there except few what say residual elements may be there or minor alloying elements will be there.

So, this is the 1XX series an aluminum alloy with copper as the major alloying element is designated as 2XX series in the series copper is the main alloying element. Next one an aluminum alloy with silicon with added copper and or magnesium is designated as 3XX series means in this series silicon is the main alloying element, but it also contains little amount of copper or magnesium are both and this series is known as the 3XX series. Next one an aluminum alloy with silicon as the major alloying element in the previous case also silicon is present, but along with silicon copper and magnesium are also present, but here in the 4XX series 1 is silicon is the main alloying element, now when the 1 silicon is present as the main alloying element or the major alloying element it is designated as 4XX series.

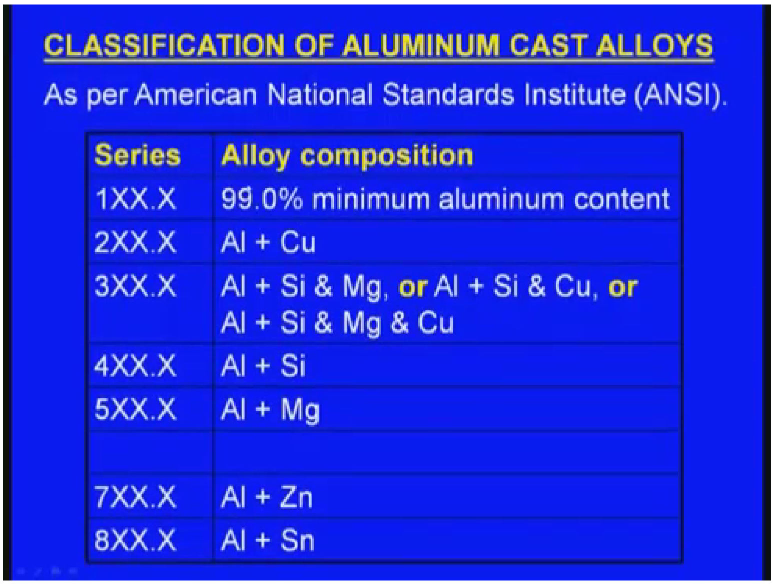
(Refer Slide Time: 18:32)



Next one an aluminum alloy with magnesium as the major alloying element is designated as 5XX series here the major alloying element is magnesium, next there will be one unused series will be there 6XX series. So, this is not used till now, next one an aluminum alloy with zinc as the main alloying element with small additions of copper magnesium, chromium, manganese, are combinations of these elements is designated as 7XX series here zinc is certainly is the major alloying element, but it also may contains small additions of copper magnesium chromium or are manganese are combinations of this, next one an what say aluminum alloy with tin as the major alloying element is designated as 8XX series.

Here tin is the major alloying element, again there is another unused series 9XX series it is not used. So, this is the basis for the classification of the aluminum alloys. So, aluminum alloys are classified based on the major alloying element and they are designated different series.

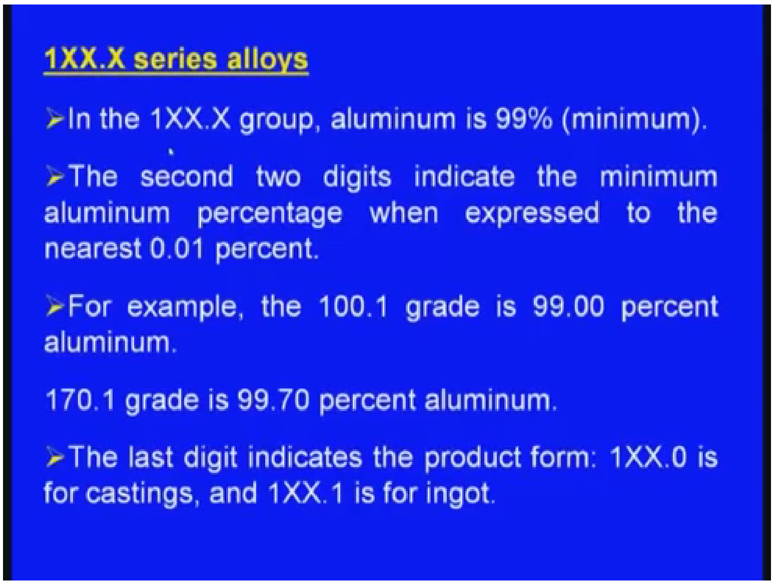
(Refer Slide Time: 19:46)



Now, this is the classification. So, what say a conclusion as per the American national standards institute ANSI again we will see how they are classified 1XX series means it is the almost the pure aluminum except that there will be what say little amounts of residual elements and minor alloying elements, 1XX are the pure alloy what say pure aluminum, next one 2XX series are the what say copper based aluminum alloys copper is the main major alloying element.

In the 3XX series silicon is the what say major alloying element along with silicon magnesium or copper or magnesium or copper will be present, in the 4XX series only silicon is the main alloying element major alloying element, in the 5XX series magnesium is the main major alloying element, in the 7XX series zinc is the major alloying element, in the 8XX series tin is the main alloying element. So, we can see. So, these are the codes we can later we will see different types of what say designations like 356 the most popularly used what say aluminum alloy. So, each what say these numerals will be interpreting some information.

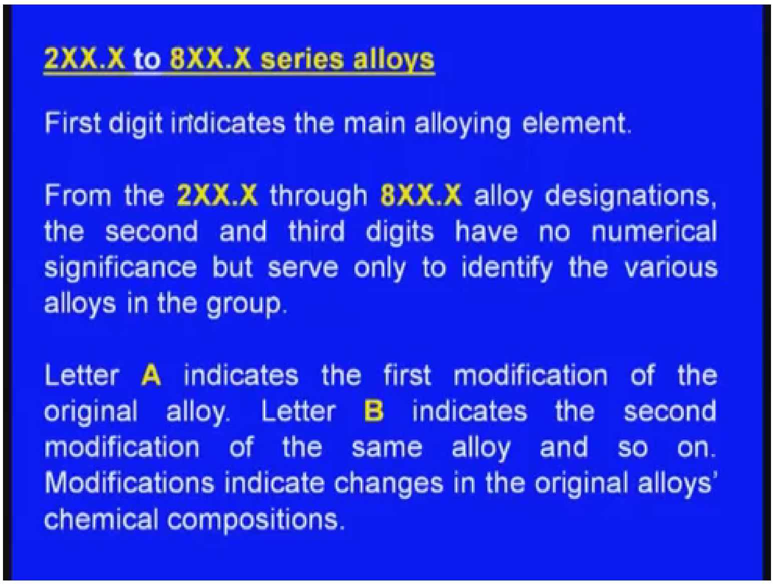
(Refer Slide Time: 21:15)



Now, let us learn about 1XX series alloys in the 1XX series aluminum is 99 percent minimum minimum there must be 99 percent aluminum sometimes it will be even more than 99 percent.

Now, the second 2 digits 1 means certainly it is the what say 99 percent aluminum is there no doubt in that, the second 2 digits indicate the minimum aluminum percentage when expressed to the nearest what say 0.01 percent. For example, you see there may be a series like say 100.1. So, this is the designation of an alloy what does it mean it means the aluminum is what say 99 percent aluminum, again sometimes there may be a what say grade 170.1 what does it mean already 1 is there means 99 definitely it will be there what is this 70 means 99.70 percent aluminum. The last 2 digits indicate the product form again we can see decimals are there like 0.1 here we can see at sometimes 0 will be there, what is the meaning right for example, 1XX 0 is for castings and 1XX.1 is for the ingots 0 means it is for the castings and 1 means the it is for the ingots.

(Refer Slide Time: 22:38)



Next let us see the 2XX series to 8XX series, first digit indicates the main alloying element starting from 2 to 8 first what say digit indicates the maining main alloying element. From 2XX X through 8XX alloy designations this second and third digits have no numerical significance, but serve only to identify the various alloys in the group, then the second what say digits they may not indicate the exact proportion of the alloys, but they will tell us about the other alloying elements the presence of the other alloying elements.

Again not only what say we can see 2XX X will be there 3XX will be there 4XX say till 8XX series are there of course, 0.2 0 will be there decimal and 0.1 will be there 0 means casting 1 means ingot now these are the suffixes, now there will be prefixes will be there like a A 356 likewise there will be a will be there B will be there what is the meaning letter a indicates the first modification of the original alloy.

Similarly, letter B indicates the second modification of the same alloy and so on modifications indicate changes in the original alloys chemical compositions. So, these are or the information about the 2XX to 8XX series.

(Refer Slide Time: 24:15)

Now, first let us see let us learn about 2XX series something more, in this 2XX series aluminum copper alloys the majority of aluminum copper alloys grades contain 4 to 5 percent copper certainly 1 someone says that the alloys designation is 2XX something means it is the major alloying element is copper because 2 is present.

Now, what is the proportion; the proportion of copper will be 4 to 5 percent. For example, so these are the important alloys important 2XX series say 2 0 1.0 2 0 8.0 2 2 triple 2 0.0 likewise. So, these are the important series now what are the applications of the 2XX series cylinder heads for automotives and aircraft engines pistons for diesel engines exhaust system parts and many more. So, these are used in the automotives.

(Refer Slide Time: 25:11)

Chemical compositions of some 2XX.X cast alloys

Desig- nation	Si %	Cu %	Mn %	Mn %	Zn %	Ti %	Other %
201.0	0.1 max .	4.0- 5.2	0.2- 0.5	0.15- 0.55	-	0.15- 0.35	Ag 0.4- 1.0
208.0	2.5- 3.5	3.5- 4.5	0.5 max.	0.1 max.	1.0 max.	0.25 max.	-
222.0	2.0 max .	9.2- 10.7	0.5 max.	0.15- 0.35	0.8 max.	0.25 max.	-

Balance: Aluminum

So, this is the chemical composition of some 2XX cast alloys and here we can see this is the designation 201.0 208.0 triple 2 .0.

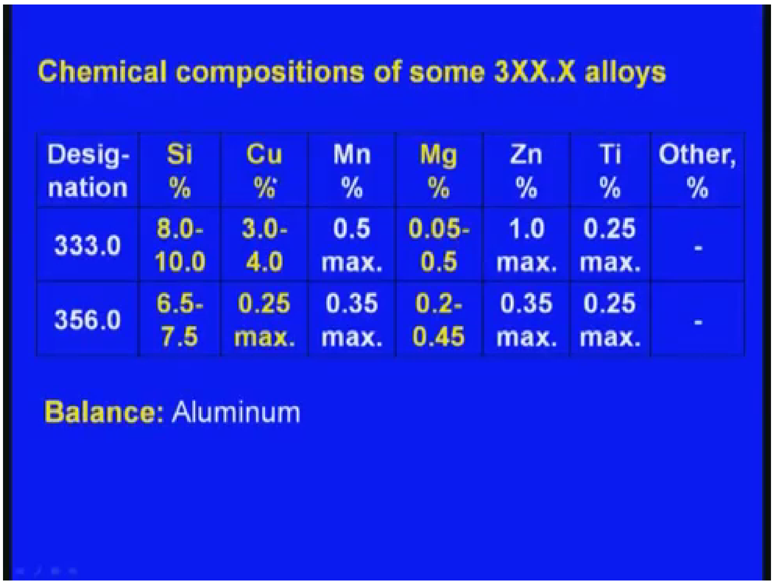
Now, these are the alloying elements silicon copper manganese here it is zinc and titanium and here we can see this is the 201 and silicon is 0.1 maximum and this is the major alloying element 4 to 5.2 and in the case of the 208. 0 silicon will be 2.5 to 3.5 and remember in this series the copper is the major alloying element and the it is proportion will be 3.5 to 4.5 again triple 2.0 maximum silicon will be 2 percent and the copper will be 9.2 to 10.7 percent and there will be other elements like zinc under titanium.

(Refer Slide Time: 26:18)

So, these are the this is the what say microstructure modifying element and balance is the iron in the what say triple X what say 3XX series means what does it mean the major alloying element will be silicon along with magnesium and copper, you can see here aluminum silicon magnesium and copper silicon is definitely present along with silicon either magnesium or copper sometimes both, the majority of these alloys grades contain 6 to 10 percent silicon 0.2 to 0.5 percent magnesium and 0.2 5 to 4 percent copper.

Important to alloys in this 3XX series are say 3 1 9.0 3 2 0.0 triple 3.0 3 5 6.0. So, this 3 5 6 is very popular and what are the applications automotive cylinder blocks car wheels aircraft fittings casings and other parts of compressors and pumps. So, these are the typical what say applications of 3XX series.

(Refer Slide Time: 27:18)



Chemical compositions of some 3XX.X alloys

Designation	Si %	Cu %	Mn %	Mg %	Zn %	Ti %	Other, %
333.0	8.0-10.0	3.0-4.0	0.5 max.	0.05-0.5	1.0 max.	0.25 max.	-
356.0	6.5-7.5	0.25 max.	0.35 max.	0.2-0.45	0.35 max.	0.25 max.	-

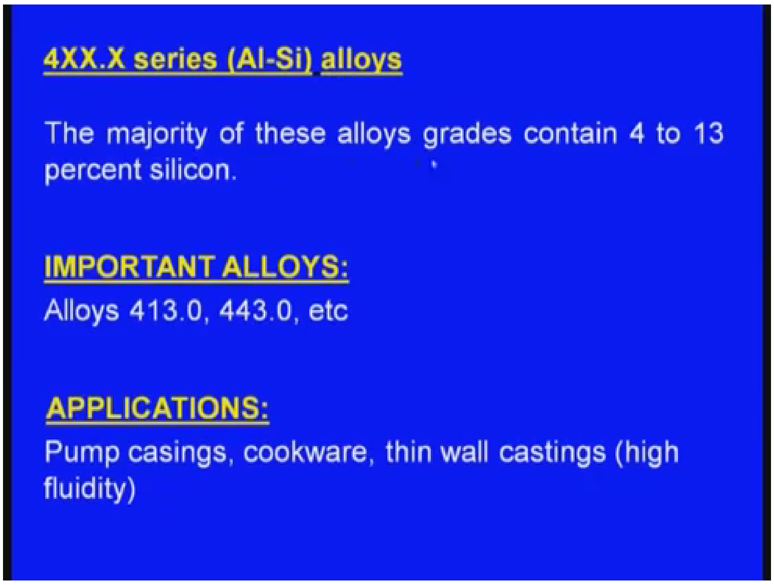
Balance: Aluminum

And here we can see. So, this is the chemical composition of somewhat say 3XX alloys.

Designation is say triple 3.0 and this is the silicon will be present from 8 to 10 percent, copper will be present 3 to 4 percent, manganese 0.5 maximum magnesium 0.0 5 2.5 percent, zinc 1 percent is the maximum titanium 0.25 percent, and 3 5 6.0 silicon will be 6.5 to 7.5 copper 0.2 5 maximum manganese 0.3 5 to and the 0.3 5 is the maximum and again it contains magnesium 0.2 to 0.4 5 zinc 0.3 5 maximum and titanium 0.2 5 maximum.

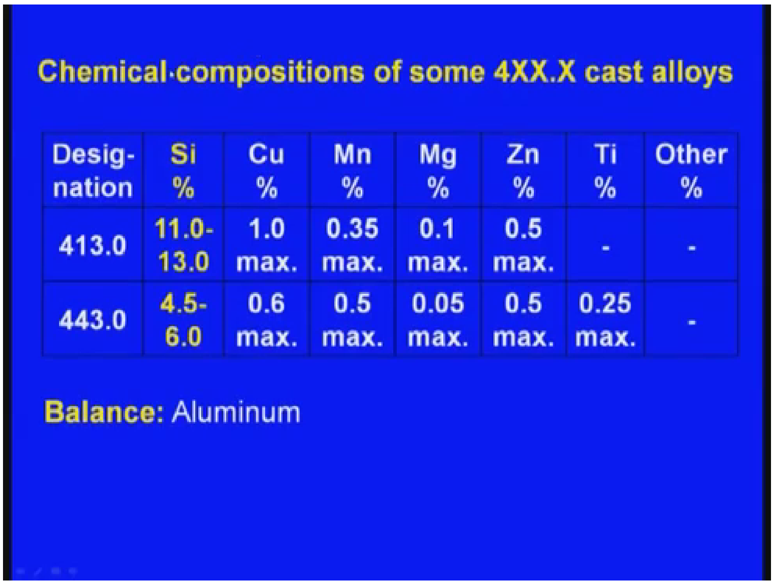
Remember in this series 3XX series silicon is the major alloying element, not only silicon along with silicon copper and magnesium are also present either copper or magnesium are both and the balance is aluminum. Next one 4XX series 4 means the majority of these alloys contain 4 to 13 percent silicon here.

(Refer Slide Time: 28:26)



The once 4 is present the major allowing element is silicon and the silicons proportion will be 4 to 13 percent and what are the important alloys in this series 413.0 443.0 and so on. And what are the applications pump casings cookware tin wall castings likewise. And remember here thin wall castings can be produced successfully why because silicon is up to 13 percent silicon offers the what say more maximum fluidity to the casting alloy why because during solidification, it what say releases latent heat of fusion because of that the fluidity will be incre enhancing that is how the thin walled castings can be successfully made using this series 4XX series. Now this is what say chemical compositions of some 4XX cast alloys.

(Refer Slide Time: 29:24)

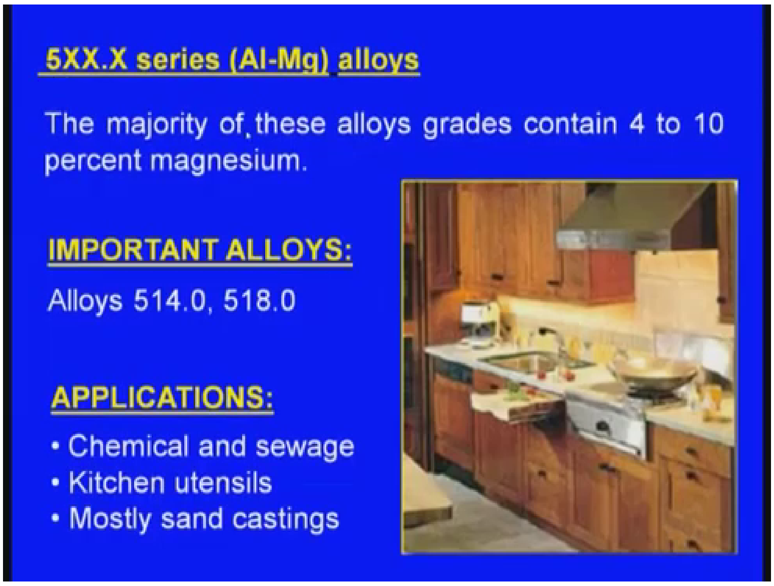

Chemical compositions of some 4XX.X cast alloys

Designation	Si %	Cu %	Mn %	Mg %	Zn %	Ti %	Other %
413.0	11.0-13.0	1.0 max.	0.35 max.	0.1 max.	0.5 max.	-	-
443.0	4.5-6.0	0.6 max.	0.5 max.	0.05 max.	0.5 max.	0.25 max.	-

Balance: Aluminum

Now, here we can see this is the designation 413.0 443.0 and the silicon composition is 11 to 13 percent, copper 1 percent maximum manganese 0.3 5 percent maximum, magnesium 0. 1 percent maximum, zinc 0.5 percent and in the 4 4 3 series silicon will be 4.5 to 6 percent copper 6 percent maximum manganese 0.5 percent maximum, magnesium 0.05 percent, maximum zinc 0.05 percent maximum and titanium 0.25 percent maximum and remember in this series 4XX series the silicon is the major alloying element and the balance is aluminum.

(Refer Slide Time: 30:22)



Next one 5XX series, these are the aluminum magnesium alloys means magnesium is the major alloying element majority of these alloys grades contain 4 to 10 percent magnesium, what are the important alloys 514.0 518.0 and these are the what say typical applications chemical and sea based kitchen utensils and mostly sand castings chemical compositions of some 5XX cast alloys.

(Refer Slide Time: 30:43)

Chemical compositions of some 5XX.X cast alloys

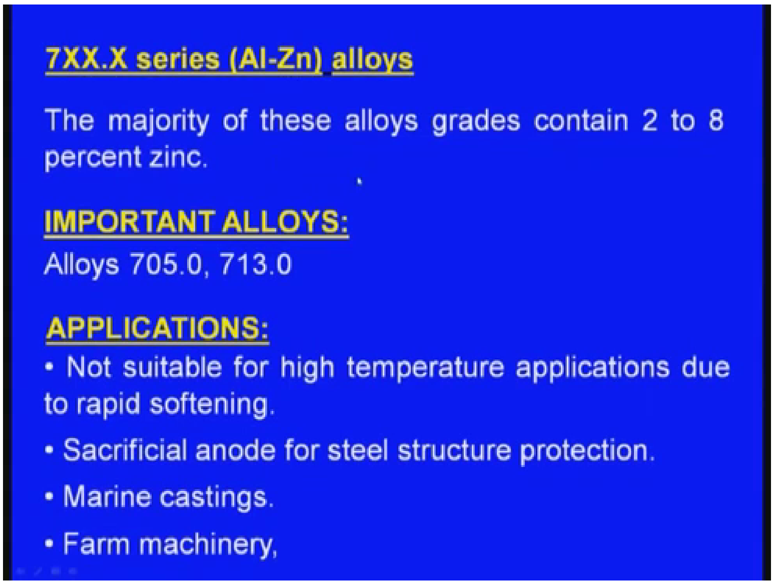
Desig-nation	Si %	Cu %	Mn %	Mg %	Zn %	Ti %	Other %
514.0	0.35 max.	0.15 max.	0.35 max.	3.5-4.5	0.15 max.	0.25 max.	-
518.0	0.35 max.	0.25 max.	0.35 max.	7.5-8.5	0.15 max.	-	-

Balance: Aluminum

So, this is the designation 5 1 4.0 and 5 1 8 .0.

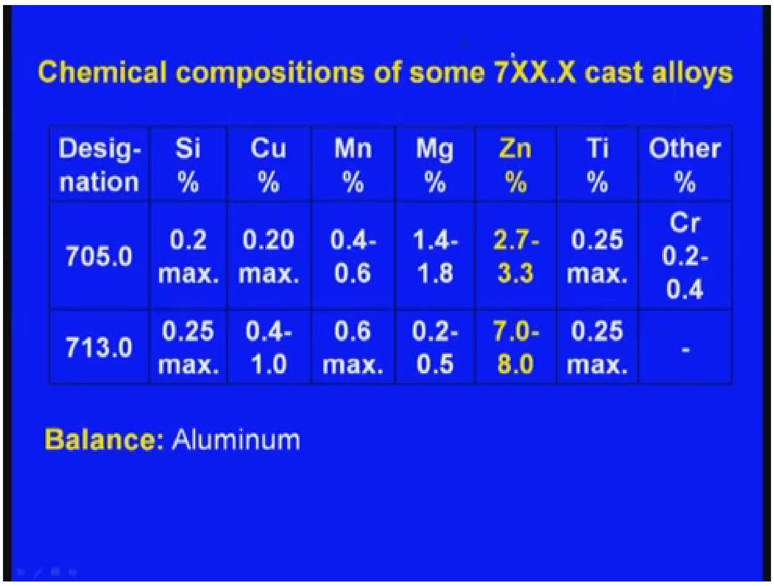
Silicon will be 0.3 5 maximum, copper 0.1 5 maximum, manganese 0.3 5 maximum, magnesium 3.5 to 4.5 zinc 0. 1 5 to maximum, titanium 0.25 percent maximum, in the 5 1 8.0 silicon will be 0.35 percent maximum, copper will be 0.25 maximum, manganese 0.35 percent maximum, and magnesium 7.5 to 8.5. Zinc will be present say maximum 0.15 and the balance is aluminum remember in this 5XX series magnesium is the major alloying element.

(Refer Slide Time: 31:41)



Now, let us see the 7XX series, what is the 7XX series the majority of these alloy grades contain 2 to 8 percent zinc; zinc is the major alloying element, now these are the important alloys like alloys 705.0 713.0. Now these are the applications these are not suitable for high temperature applications due to rapid softening because zinc is present it melts at a very low temperature. So, it is they are not suitable for high temperature applications right sacrificial anode for steel structure protection. So, these are used as the sacrificial anode for steel steel structure protection against corrosion. Next one marine castings right form machinery. So, this zinc offers resistance against corrosion

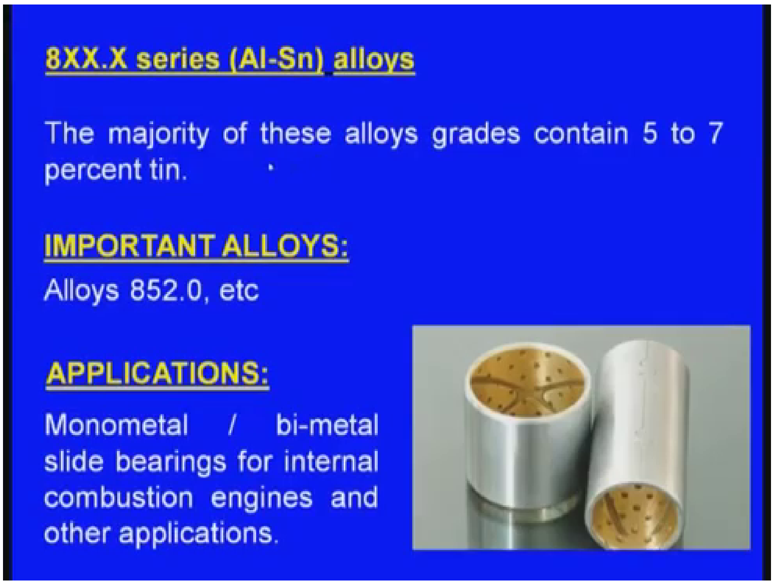
(Refer Slide Time: 32:31)



Designation	Si %	Cu %	Mn %	Mg %	Zn %	Ti %	Other %
705.0	0.2 max.	0.20 max.	0.4-0.6	1.4-1.8	2.7-3.3	0.25 max.	Cr 0.2-0.4
713.0	0.25 max.	0.4-1.0	0.6 max.	0.2-0.5	7.0-8.0	0.25 max.	-

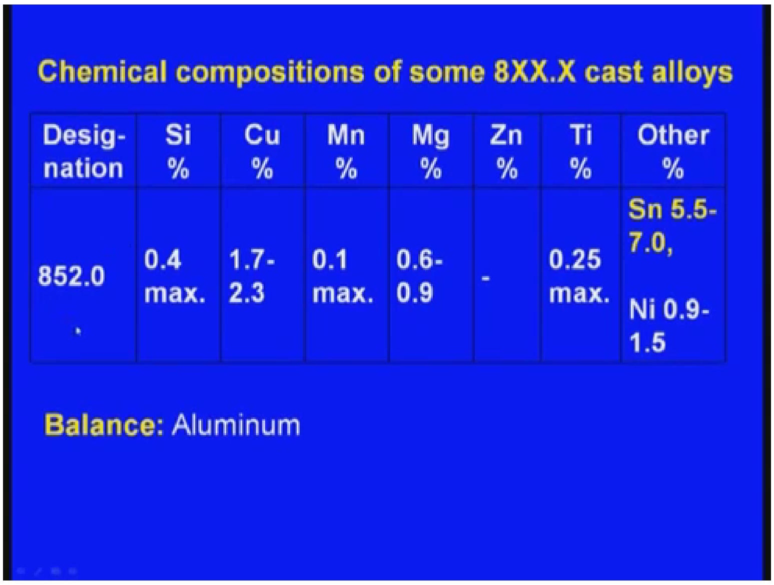
Now these are the chemical what say compositions of somewhat say 7XX cast alloys designation you see. So, this is 7 0 5.0 7 1 3.0 in the 7 0 5.0 silicon will be 0.2 to maximum percent, copper will there will be copper 0.2 maximum manganese 0.2 4 2.6 percent, magnesium 1.4 to 1. 8 percent, zinc 2.7 to 3.3 titanium 0.25 percent maximum and there will be other elements like a chromium 0.2 to 0.4 percent, and in the 7 1 3.0 .2 5 percent maximum silicon will be there and copper will be from 0.4 to 1 percent, manganese 0.6 maximum percent, magnesium 0.2 to 0.5 percent, zinc 7 to 8 percent, and titanium maximum 0.2 5 percent, will be there and the balance is aluminum and remember zinc is the major alloying element in the 7XX series.

(Refer Slide Time: 33:35)



Next let us see the 8XX series. So, in the series tin is the major alloying element, majority of these alloying grades contain 5 to 7 percent tin important alloys alloys says 7 5 to 0.0. So, this is the most important alloy now what are the applications monometal bi metals slide bearings for internal combustion engines and other applications.

(Refer Slide Time: 33:56)



Chemical compositions of some 8XX.X cast alloys

Designation	Si %	Cu %	Mn %	Mg %	Zn %	Ti %	Other %
852.0	0.4 max.	1.7-2.3	0.1 max.	0.6-0.9	-	0.25 max.	Sn 5.5-7.0, Ni 0.9-1.5

Balance: Aluminum

These are the chemical compositions 852.0 silicon 0.4 maximum copper 1.7 to 2.3 manganese 0.1 percent maximum magnesium 0.6 to 0.9 there would not be zinc and titanium 0.2 5 percent maximum and other elements like tin point are the not other elements. So, this is the major alloying element here.

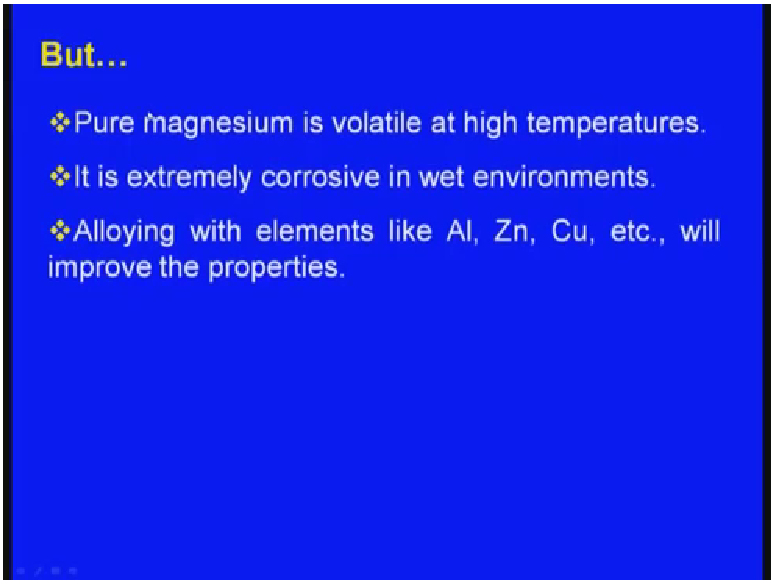
5.5 to 7 percent and other alloying elements like nickel 0.9 to 1 5 1.5 percent and the balance is aluminum, here in this series tin is the major alloying element now. So, far we have completed the aluminum cast alloys now let us see the magnesium cast alloys.

(Refer Slide Time: 34:37)

Now, the first question is why magnesium it is the lightest structural metal it is density is 1.8 grams per cubic centimeter whereas, for aluminum the density is 2.7 grams per cubic centimeter here it is 1.7 means almost to one gram less compared to the aluminum.

Can be cast thinner and faster can be machined easier than aluminum the better dimensional stability high specific strength and high damping capacity good thermal conductivity and 100 percent recyclability. So, these are all the benefits compared to the aluminum alloys that is why slowly magnesium alloys are replacing aluminum alloys.

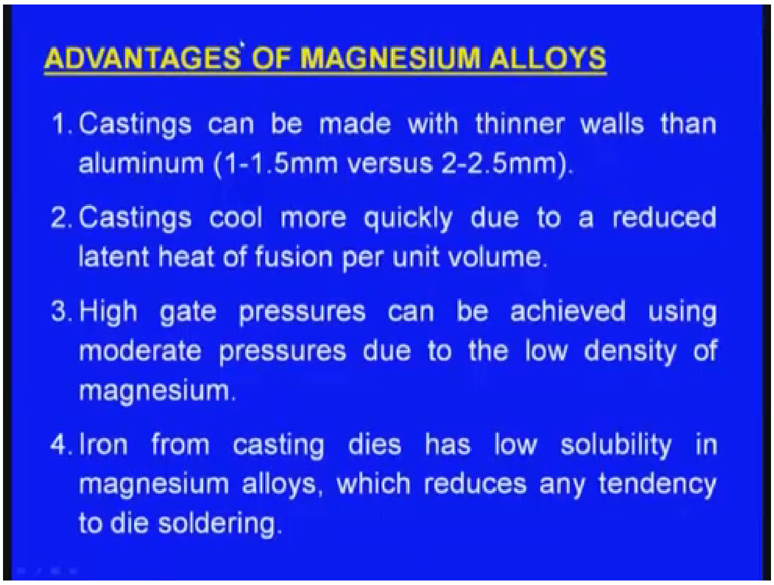
(Refer Slide Time: 35:24)



But pure magnesium is volatile at high temperatures it is extremely corrosive in wet environments alloying with elements like aluminum zinc copper etcetera will improve the properties.

So, at any cast we cannot use the pure magnesium right we have to alloy it with different elements like aluminum zinc copper and so on.

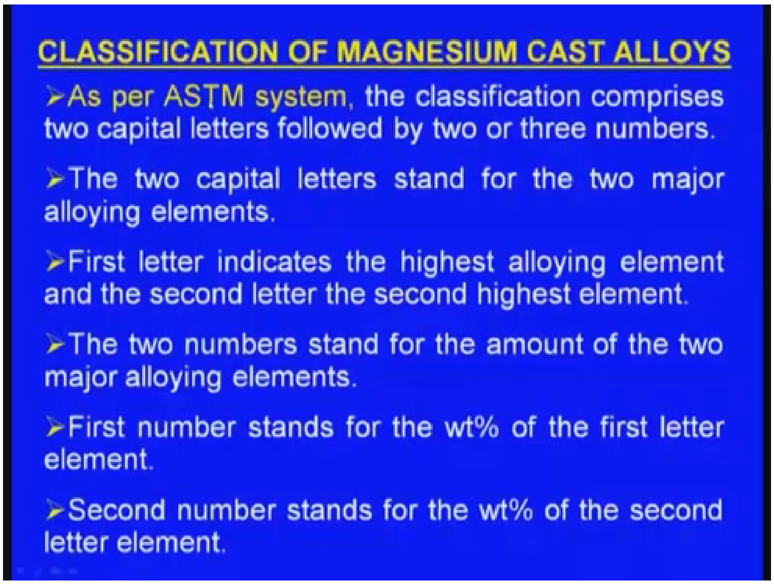
(Refer Slide Time: 35:48)



Now, these are the advantages of magnesium alloys castings can be made with thinner walls compare to aluminum 1 to 1.5 mm up to 1.1 1.5 1 mm can be made castings cool more quickly due to a reduced latent heat of fusion per unit volume the what say solidification time is much lesser compared to aluminum, high what say gate pressures can be achieved using moderate pressures due to the low density of magnesium mainly it is used in the what say die castings.

So, that time say during the pressure die casting we need to what say apply higher pressure, but when we use the magnesium even what say moderate pressure will be enough because why there is the density of the magnesium means low. Iron from castings casting dies has low solubility in magnesium alloys, which reduces in a tendency to die soldering. Now this is mainly used in the die castings right. So, what is the problem with a die castings. So, in the die castings the dies are the ferrous alloys now what happens the iron from the dies may react with the magnesium; that would not happen here in the case of the aluminum alloys it may happen, but here it has got the low solubility that is how this soldering defect can be minimized.

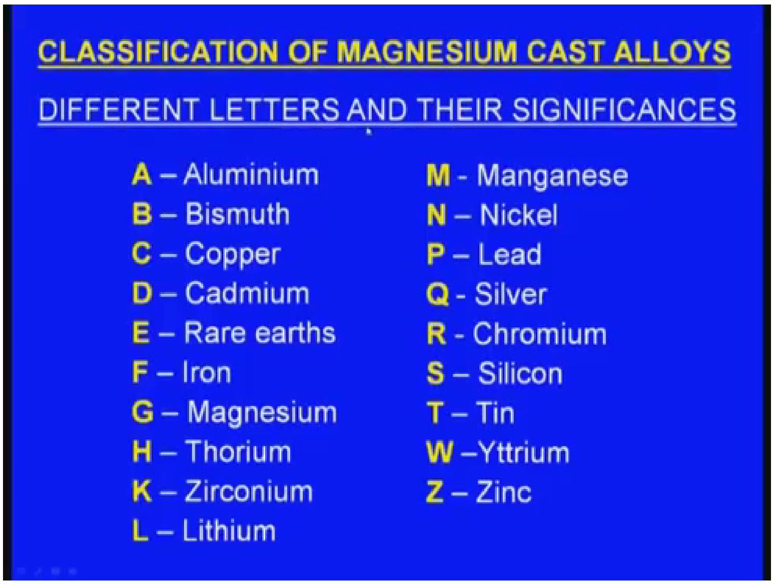
(Refer Slide Time: 37:19)



Again now we will see the classification of the magnesium cast alloys, as per ASTM system the classification comprises 2 capital letters followed by 2 or 2 or 3 numbers there will be 2 letters will be there, again followed these 2 letters will be followed by 2 or 3 digits the 2 capital letters stand for the 2 major alloying elements. The first letter indicates the highest alloying element, and the second letter indicates the second highest alloying element the 2 numbers after the 2 letters there will be 2 numbers will be there.

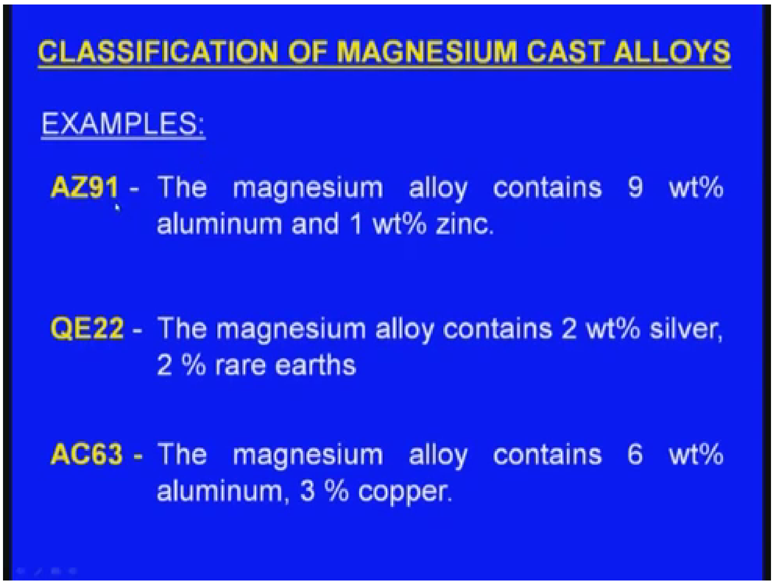
These 2 numbers stand for the amount of the 2 major alloying elements the first number stands for the percentage weight of the first letter element, second number stands for the percentage weight of the second alloying element.

(Refer Slide Time: 38:09)



Now, different letters and their significances in they what say classification we will see for example, A Z 91 what does it mean say aluminum will be the major alloying element, zinc will be the next major alloying element, and 9 indicates the proportion of aluminum and 1 indicates the proportion of zinc; likewise several letters are used we can see here a means aluminum B means bismuth, C means copper, D means cadmium, E means rare earth metals, F means iron, G means magnesium, H means thorium, K means zirconium, L means lithium, M means manganese, N means nickel, P means lead, Q means silver, R means chromium, S means silicon, T means tin, W means yttrium, and Z means zinc.

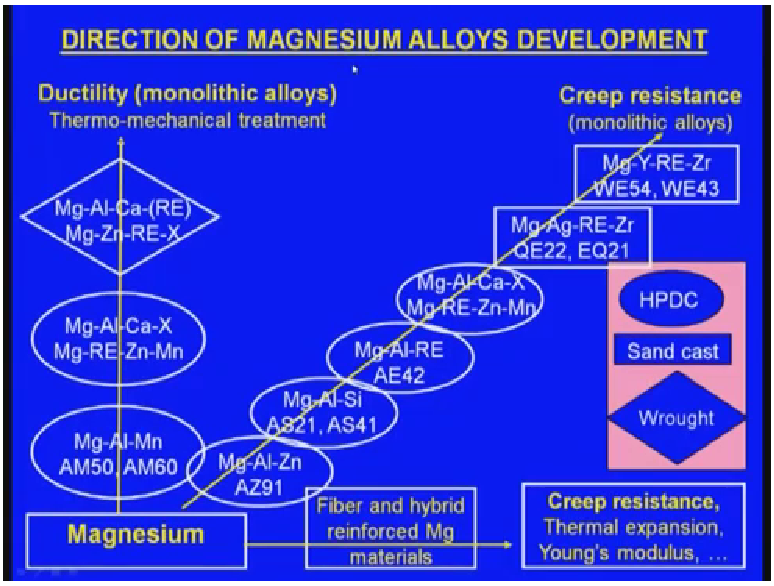
(Refer Slide Time: 39:02)



Examples A Z 91 this is the most popular alloy the magnesium alloy contains you see aluminum here this is a magnesium alloy and aluminum is the main alloying element, next one zinc is the second alloying element the magnesium alloy contains 9 percent aluminum and 1 percent zinc that is the meaning of A Z 91.

Similarly Q E 2 2 Q E 20 2 what does it mean the magnesium it is say magnesium alloy it contains 2 percent silver and 2 percent rare earth metals, means here Q is present that in represents silver presence of silver is there that represents the presence of rare earth metals, 2 percent silver and 2 percent rare earth metals. Next one A C 63 you see this is again a magnesium alloy it contains 6 percent to here a a means aluminum and it contains 3 percent copper.

(Refer Slide Time: 40:00)



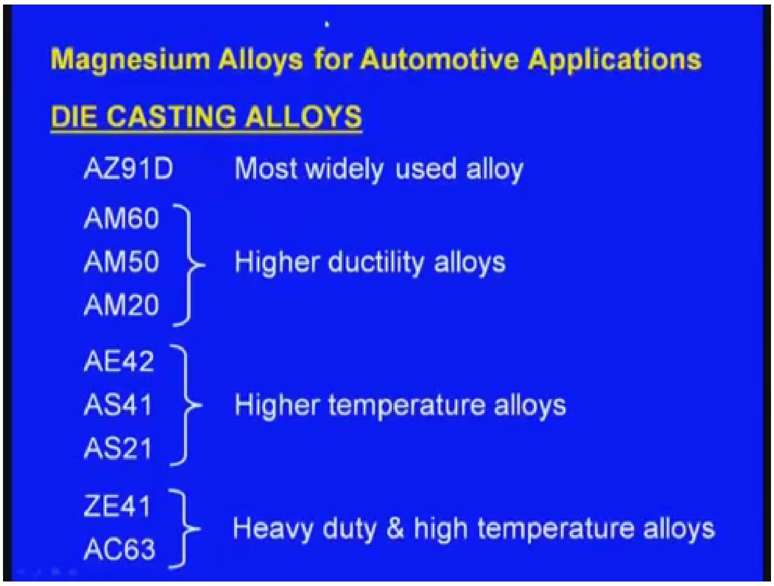
Now, this is the direction of magnesium alloys development and this is the magnesium and here we can see as we what say add aluminum magnesium sorry manganese it will be A M 50 A M 60 and here we will be adding aluminum, calcium, and we can see here and rare earth metals zinc manganese and here will be adding aluminum, calcium, rare earth magnesium zinc and rare earth likewise.

So, this way when we what say mix the alloying elements we get ductile what say alloys and here we can see here we are adding aluminum and zinc and it may it becomes AZ 91 and here we are adding aluminum and silicon it becomes AS 20 1 AS 41 here we are adding aluminum and rare earth metals it becomes AE 42 and here we are adding aluminum calcium and so on. And here we are adding silver, rare earth metals, zirconium it becomes Q E what say 22 E Q 21 and here we are adding yttrium rare earth metals zirconium and it becomes W E 54 W E 4 3.

This side when we what say keep on alloying the elements here thus we will be getting creep resistance alloys, the alloys will have the very good creep resistance and we can see here. So, here we can see this what say ellipse indicates the high pressure die casting means these alloys are used for the high pressure die casting these alloys are also used for the high pressure die casting, but this one we can see this diamond is for the wrought alloys.

So, these are not the cast alloys, again we can see this rectangle indicates the san they they are meant for the sand castings these are the alloys here we can see this is one set and this is the another set. So, these 2 groups they are useful for the sand castings and here we can see fiber and hybrid reinforced magnesium materials and if we keep like what say add like this we will be getting creep resistance alloys, thermal expansion alloys, and youngs modulus will be improved likewise we can improve the what say develop the alloys in 3 directions now magnesium alloys for automotive applications.

(Refer Slide Time: 42:23)



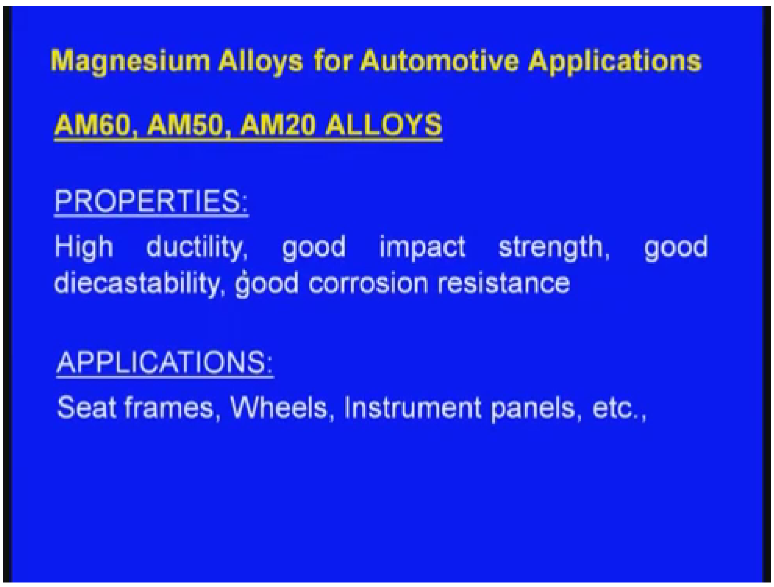
So, these are the die casting alloys AZ91D it is the most widely used alloy, next one AM60 AM50 AM20 these are the higher ductility alloys, next one AE42 AS41 AS21. So, these are the higher temperature alloys, next one ZE41 AC63 these are the heavy duty and high temperature alloys AZ91D alloy properties good room what say temperature strength excellent die castability and good corrosion resistance.

(Refer Slide Time: 42:57)

What are the applications steering column brackets, 4 wheel drive transfer case, manual transmission case, clutch pedal brake pedal steering column brackets crankcase, chain housing steering box rear link arms and subframe and so on.

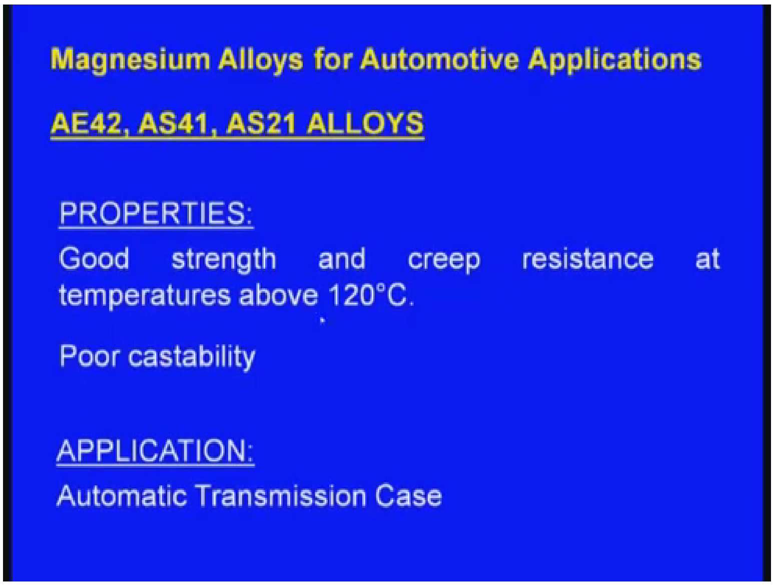
So, these are the applications of AZ91D alloy next one let us see the applications of AM60 AM50 and AM20 alloys.

(Refer Slide Time: 43:31)



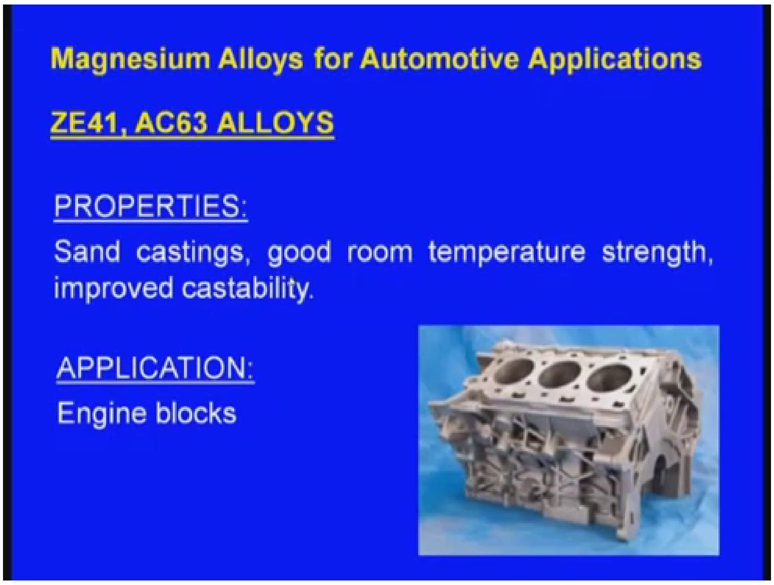
These are what are the properties they have high ductility good impact strength good die castability and good corrosion resistance and what are the applications seat frames wheels instrument panels and so on; next 1 AE42 as 41 and as 21 alloys.

(Refer Slide Time: 43:52)



What are the properties good strength and creep resistance at temperatures above 120 degree centigrade, but poor castability applications automatic transmission case next one ZE41 AC63 alloys.

(Refer Slide Time: 44:06)



What are the properties sand castings good room what is your room temperature strength and improved castabilty and applications. So, these are used for making the what say engine blocks.

Friends in this lecture we have seen different or what say aluminum alloys and different aluminum cast alloys and different magnesium cast alloys, and we have seen what say how the aluminum cast alloys have been what say classified they are classified based on the major alloying elements the 1XX series 2XX series and so on. And we have also seen how the magnesium what say cast alloys have been classified like AZ91 and so on again. So, this AZ91 remember. So, there will be for 2 letters will be there these 2 letters indicate the 2 main alloying elements and there will be 2 digits will be there, these 2 digits will be reflecting the or indicating the proportion of the 2 alloying elements likewise. So, there will be different classifications of the magnesium alloys will be there we have seen.

And nowadays slowly the magnesium alloys are replacing the aluminum alloys, why because the density of magnesium alloys is what say lesser than the density of the magnesium alloys, and there castability is very high even very thin sections can be made. So, that is how magnesium alloys are gaining more and more importance these days, but the problem is with a magnesium alloys while melting.

So, the melting has to be done very carefully, the magnesium can explode if it is melted in a open atmosphere that is why always the magnesium is melt what say melted in a closed environment closed and controlled environment, that is how the melting of magnesium becomes expensive no problem it may become little expensive compare to the melting of aluminum, but the properties of magnesium alloys are much better compare to the properties of aluminum alloys.

So, in the next class we will be seeing other what say nonferrous cast metals until then.

Thank you and goodbye.