Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations
Prof. D.K. Dwivedi
Department of Mechanical and Industrial Engineering
Indian Institute of Technology-Roorkee

Lecture-43
Surface Modification Techniques: Fundamentals of surface Modification by Weld Surfacing

Hello I welcome you all in this presentation related to the subject fundamentals of surface engineering and you know we are talking about the surface modification using third type of the method where in a layer of the required material having the requisite set of the properties is applied on to the surface of the substrate so that require expected improvement in the properties of the surface can be enhanced for improved wear and tribological performance. So, in this connection means what are the basic fundamentals related with the various processes which are used for surface modification by developing a layer on to the surface of the substrate.

In the previous presentation have talked the sum of those fundamentals and his presentation I will be talking about those are fundamental aspects related to surface modification where in the welding is used as a process for surface modification of the substrate.

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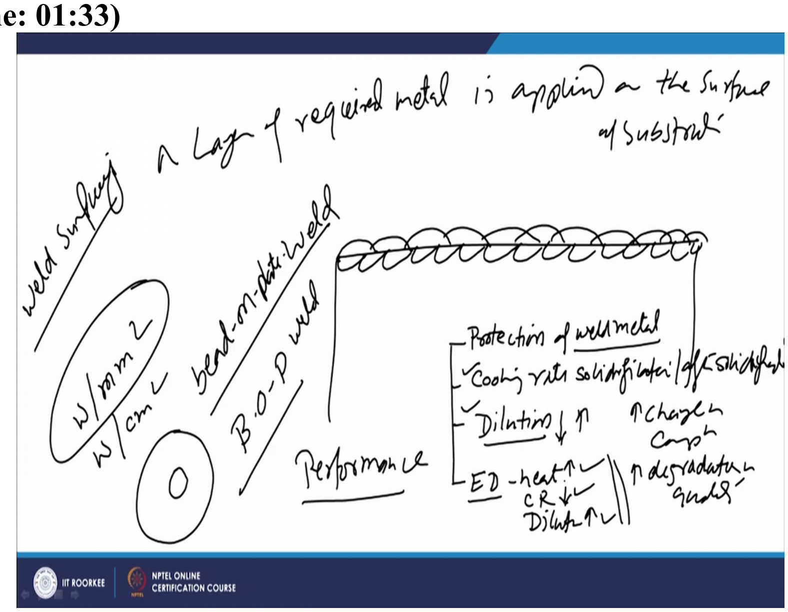

So, you know in case of the welding basically layer of the required material this is selected as per the requirement of the set of the properties which are desired at the surface layer of the required material is applied on the surface of substrate in this approach which is called weld surfacing when metal is deposited using a welding process. So, like this is a surface of the substrate so, we have to melt the substrate material up to certain depth while depositing the selected material on to the surface like this?

So, this kind of the layer is called bead on plate weld it is in short it is termed as BOP weld. So, bead ob plate weld is deposited to have layer of the required material on to the surface of the substrate so, properties of the surface can be enhanced. However performance of such a layer being deposited is influenced by performance means mechanical and tribological performance of such kind of the layer which is being applied on to the surface of the substrate is influenced by the various factors.

Like how effectively we are able to protect the metal while it is being applied or while bead on plate is being where it is being developed. So, the protection of the weld metal when the bead on plate weld is being applied. The second aspect is what is the cooling rate? It experiences during the solidification. So, cooling rate experienced by the bead on plate held during solidification or after solidification both have effect on the properties of layer which is been applied by weld surfacing.

Then we have the dilution the kind of change in chemistry of the metal being applied on to the surface of substrate by fusing both. In case of the weld surfacing so what is the extent of change in composition that is expressed in terms of the dilution. So, greater is the dilution greater will be the change in composition of the layer of the metal which is being applied. So, where will be greater possibility for increased degradation in quality?

So, it is always decide the dilution is as less as possible and like dilution and cooling rate both to a great extent are influenced by the energy density associated with the that welding process which is being used. So, in general how much energy is being applied over unit area so that we express in terms of the watt per mm square or watt per centimetre square, mm square is more commonly used unit?

So, over small area we are applying the large amount of the energy or over a large area we are applying the given same amount of the energy so that will bring in the change in the energy density and this will in turn affect the heat which is required for melting and if so if the heat required for melting is increases in case of the lower energy density than it will be reducing the cooling rate it will be increasing the dilution.

So, it is important that what is the energy density associated with the particular welding process which is being used. Lower is energy density increased heat input lower cooling rate increased dilution and these will this kind of practice will tend to compromise with the quality of the performance of the weld surfacing which is being applied.

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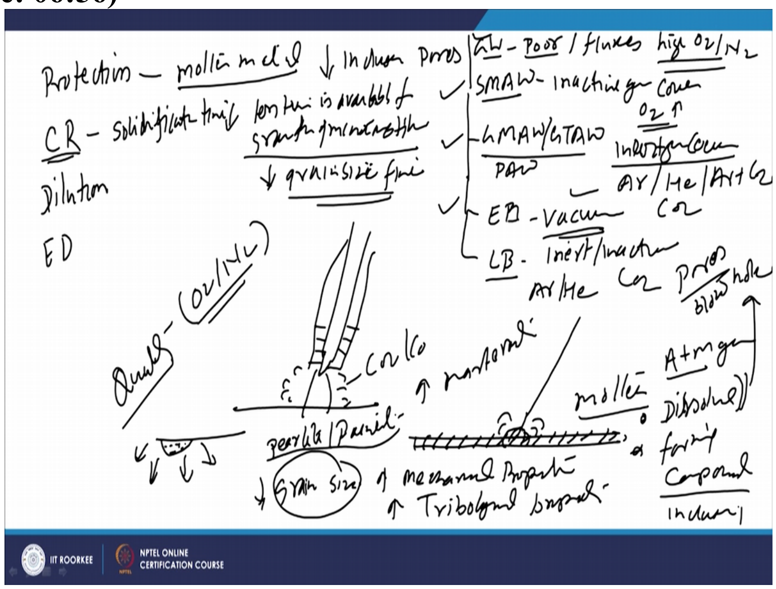

Now will look into these aspects little bit in greater detail so we have the aspects like protection the cooling rate, dilution and energy density associated with the process, so we know that when the metal is brought in see what we do in the weld surfacing either the electrode or the filler metal which is being applied which is that should be melted and a thin layer of the substrate should also be melted and interfacing of both molten metal if you will be leading to the formation of the bead on plate or weld surfacing.

So, you know since the things are brought in the molten state and at high temperature will have tendency to interact with the atmospheric gases. So, when the molten metal interact with the atmospheric gases it can either dissolve the gases or it can form some kind of the compounds like oxides, nitrides. So, desolution of the gases and their limited escaping tendency will be leading to the formation of the pores or the blow holes.

While in case of the formation of the compounds due to the interaction of the molten metal with the atmospheric gases it will be leading to the formation of the inclusions. So, it is not good that molten metal is interacting with the atmospheric gases which are present all around. And therefore we need proper protection and for this purpose in different welding processes different production approaches used.

So, like protection of the molten metal is needed to reduce the formation of the inclusions, pores and other discontinuities which are being formed due to the interaction of the molten metal with the atmospheric gases and therefore protection is needed for protection in case of like say gas welding it is very poor because we primary use the fluxes which will be interacting with impurities and will be helping to clean it.

So, basically the fluxes are used to remove the impurities and the compounds which are being formed in general is poor and this happens from related to the higher oxygen and nitrogen concentration in the weld which is being produced. While in case ever in case of the shielded metal arc welding process it is the thermal decomposition of the flux coating leads to the formation of the inactive gases, gas cover all around the pool.

So like there is electrode having the coating all around the corner of the electrodes and arc is established between the substrate and the electrode and due to the heat of the arc is flux coatings will be thermally decomposed and will you producing the inactive gases all around it in form of CO, CO_2 and is inactive gases value forming a blanket or cover all around the molten pool which will be protecting the molten metal from the atmospheric gases.

Inactive gas cover is formed this is somewhat better than what we get in case of the gas welding but still oxygen content is higher in case of the shielded metal arc welder deposited using this process. While in case of the gas metal arc welding or gas tungsten arc welding processes we use inert gas cover to protect the molten pool from interactions with the atmospheric gases and for this purpose we may use Argon or Helium or mixture of the Argon plus carbon dioxide or even CO_2 is also used in case of the steel.

If there the ferrous metals are to be processed by them is ferrous metals are to be deposited then even CO_2 can also what to provide the required protection. Then for plasma also in invariably the inert gas mixture is used for electron beam welding deposition using the electron beam process we use basically vacuum to take care of all atmospheric gases. So, that they do not interact with the molten metal.

While in case of laser beam that can be performed under the influence of the inert or inactive gases inert gases like Argon or Helium inactive gases like CO2. So, these are the different approaches associated with the different processes. Since the approach of the protection of the molten metal from the atmospheric gases is different in each of the processes and that is why the quality of the bead on plate which is deposited with regard to the oxygen and nitrogen content which is there in the bead on plate weld that will be different.

Because we are using the different approaches for protecting the molten metal from the atmospheric gases and therefore the presence of impurities are also defer. So, specially the cleanest well will be produced by the vacuum is processes then may be GTW process also results in very low level of oxygen and nitrogen content. And if we have very few impurities and these gases then chances for inclusions porosity etcetera will be reducing and that in turn will be helping to increase the performance of the bead on plates surfacing.

Now the cooling rate is another aspect in case of the cooling rate like cooling rate affects the solidification time like we have got one bead on plate pool of the molten metal which is to solidify the solidification time will be depending up on how fast it is extracted from the molten zone if our heat input is less than the surrounding material will be cool and heat will be extracted at a faster rate.

So, this will be leaving to the increased cooling rate and increased cooling rate measure the solidification time is reduced and reduce the solidification time or increased cooling rate means less time is available for growth of micro constituents which are there and less available availability of less time for growth of micro constituents means the temperature value reducing from the molten melting point to the room temperature at a much faster rate.

And therefore the time available for growth of micro constituent is reduced and that in turn will be reducing the grain size. So, it will be leading to the fine grains and you know that as the grain size is reduced there is improvement in mechanical properties in general hardness, toughness, ductility, fracture, resistance all improve. So, improvement in mechanical properties and this improvement in mechanical properties will also be leading to the improvement in tribological properties.

So, it is important to see that how the change in welding processes change in the conditions which are being used for depositing bead on plate will be affecting to the cooling rate and which in turn will affect the kind of the solidification time which would be experienced by the in the molten metal and during the bead on plate deposition and that in turn will be effective microstructure as well as the mechanical properties.

Apart from the grain size sometimes if the material is having the tendency to get tendency for the hardenability then it will be leading to the change of the phases also like under the low temperature low cooling rate conditions we may get perlite, bernite kind of the phases. But if the cooling rate is high then we may find the martensitic transformation. So, not just the grain size is affected because of the cooling rate.

But we may also find their the different types of the phases are being formed and a difference in phases will further lead to the change in mechanical properties

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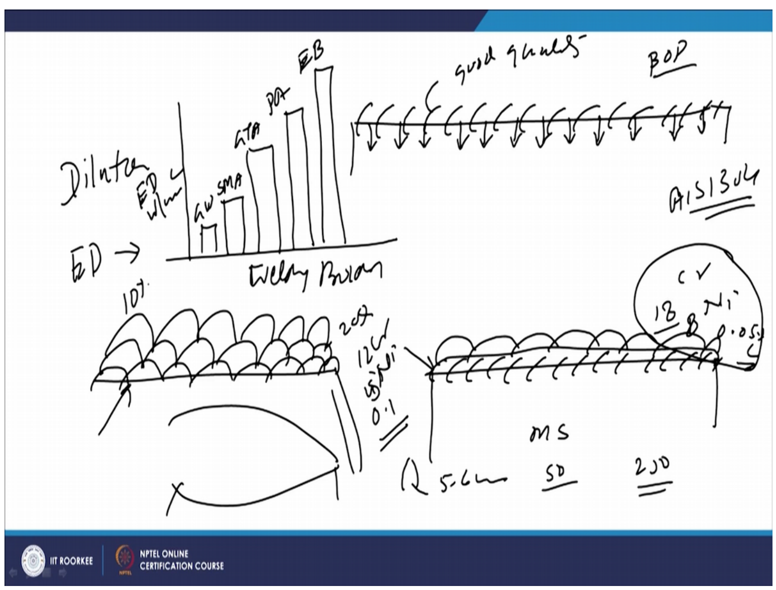

Now other two aspects are like dilution or like dilution and the energy density. Now we know that the cell the process of the weld surfacing for surface modification is based on the approach of applying a layer of the good quality material over the surface. So, that required improvement in properties can be achieved. So, the material which is being applied is really of the good quality.

And but when it is applied using the weld surfacing part of the substrate will also be melted. So, the composition of the material being applied is modified. The extent of change in composition of the metal which is being applied after the deposition of bead on plate will depend up to what extent that base metal has been melted and that in turn determining extent up to which the change in composition of material taking place.

So, this in turn directly affects mechanical properties and the quality of the surface layer which is being developed. For example like say when we have them mild steel as a substrate and we are applying the austenitic stainless steel, mild steel cost like 50 rupees kg and austenitic steel cost in like 50 250 rupees kg. So, there is a 5 times 5 fold change in the price. Good quality materials will obviously we are offering the better combination of the properties.

And at the same time it will be costlier one but when one layer is applied like this we find that austenitic stainless steel which was having 18 chromium 8 Nickel and very limited carbon content life. 05%. So, this is expected to be of the good quality material when it is being applied life AISI 304 kind of the material when is being applied. But when mixes with mild steel after the melting then maybe reduction in the chromium content which reduce the extent of the substrate melting.

And the chromium contain which may be reduced as per the extent of the substrate melting chromium content may come down to the 12 %, nickel will come down to the 4% or 5% and the carbon content may increase because mild will be having the higher carbon content like it may reach to the .1. So, there can be significant change in the composition of the layer which is being applied.

So, this is this is the story of say for the first layer if we apply the second layer then of course the extent of dilution on the kind of change in composition of the bead on plate material which is being applied that will be less. So, the extent of dilution will keep on reducing as the number of layers being applied. So, if you see here like when one layer is applied dilution level maybe 20%. When the second layer is applied dilution may come down to just like say 10 %.

The third layer may further leading to the dilution which means the extent of change in composition of the surface layer material which is being applied in form of the bead on plate that will be reducing. So, degradation in composition, composition modification due to the division that you were reducing as we keep on increasing number of layers but the first layer of course which directly mixes with the molten metal its composition is most severely affected and maximum change in composition is experienced in that case.

Energy density is it is another important factor energy density of the different welding processes is different like if here we have the welding processes in the x-axis just to understand and energy density in watt per mm square in the y-axis gas welding offers the lowest energy and density because the flame is very wide and energy whatever is being transferred that spreads over a larger area so energy density is less.

While in case of arc, arc is of more or less of like 5, 6 mm diameter of the arc at the bottom. So, energy density is high for a given set of the parameters if we compare with the gas welding. So, it offers high energy density for shielded metal arc welding process. Gas welding and gas tungsten arc welding process will be offering the further higher energy density and the plasma will be offering the further higher energy density than we have the laser and electron beam. So, there is a continuous change in the energy density is associated with the different processes.

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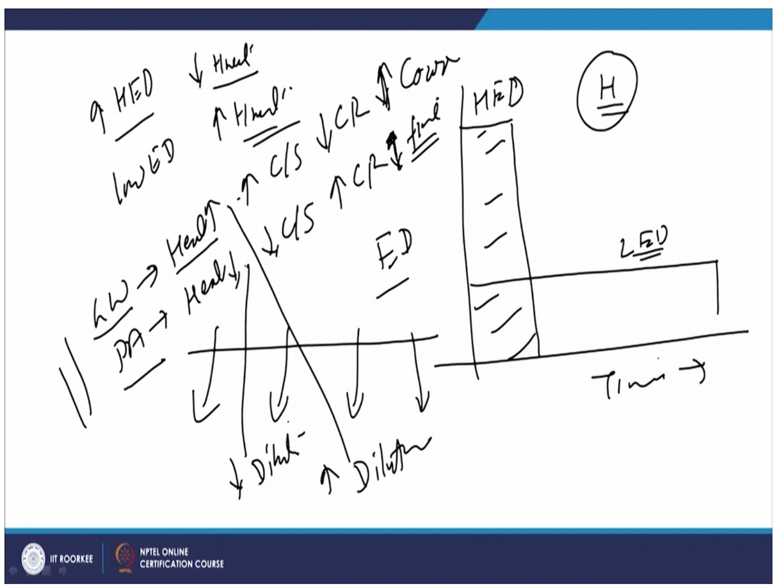

Now you understand like if H is the amount of heat required under ideal conditions then using the process which is offering the low energy density we need to supply the heat for longer time using the low energy density process. So, that requirement of the heat can be supplied so this is simple time you need to supply for longer time when the energy density is high then in a it is required to supply the energy for shorter period for same amount of the heat.

But we know that mean energy is transferred for longer period lot of heat energy will be distributed to the underlying low-temperature base metal. And that is why actual amount of heat required for melting using the low energy density process that is higher as compared to the high energy density process. Because the amount of heat which is transferred to the underlying base metal that is significantly lower in case of the high energy density process.

So, that is why what we in general say that if the process of the high energy density than it will be requiring the less heat input for achieving the fusion for developing the weld surfacing. So, if you see; on the and reverse is true for like low energy density process will require higher heat input. So, like the gas welding will be requiring the higher heat input as compared to the like plasma arc welding.

And if the for gas welding heat input is high it will be offering the very large cross sectional area of the bead on plate it will be offering the lower cooling rate and it will be needing to the coarse of grain structure and this will be degrading the quality of the weld corporation which is being produced. On the other hand higher energy density associated with the plasma arc welding leading to the reduced heat input required for fusion.

Reduced the cross section of the bead on plate which will be produced at leading to the higher cooling rate and final grain size so this is coarse grain size and here will be getting the fine grain size. And fine grain size in general reserves in much better quality with regard to the mechanical properties and tribological properties. Further there is one more properties with respect which can be added is the lower energy density her heat input greater will be the dilution level.

While for higher energy density process like plasma the dilution level is reduced. So, this is the difference associated with the different energy density is associated with the various processes. So, this is the kind of relationship between the various aspects associated welding processes which will be affecting the mechanical properties of the weld bead on plate surfacing deposited by the various welding processes.

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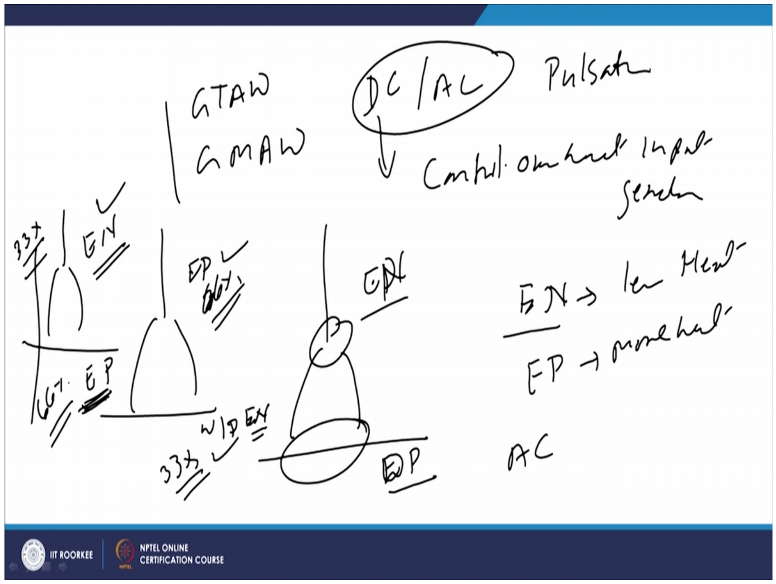

There is another aspect associated with the advancement of some of the processes like simple gas tungsten arc welding or gas metal arc welding. Conventionally both these this can work both on AC as well as DC. But if you are using DC at allows the control over the heat input heat generated by the arc. When we use the AC the heat generation in the both the ends is equal. While in case of the DC we can select the polarity suitably like electrode can be made negative using the electrode negative polarity work piece can be made positive or reverse is also possible.

We know that more amount of the heat is generated when work piece is made a positive then also whatever and is and is connected to the positive or negative terminal you will see that electronegative whatever it is that will be generating that will that and will be having the less heat generation while wherever and with the electrode positive more amount of the heat is generated.

But in case of AC's the polarity keeps on changing on every half cycle so the amount of heat being generated at both ends will be equal. Say for example if you want more heat generation then this electrode will be made positive and work piece will be made negative is work piece it will you made electrode negative. On and if we want that more heat is generated in the work piece site, so work piece will be connected to the positive terminal.

So it will be making electrode positive polarity work piece will be connected to the positive terminal and the electrode you connected to the negative terminals EN and EP electronegative or this is the reverse this is the straight polarity and in otherwise it is reverse polarity. So, reverse polarity when electrode positive and work piece is negative. Straight polarity is when electrode is negative and work piece is positive.

So in this case will be having the about 33 % of heat generation in the electrode side and 66 % of the heat generation in the work piece side or in the reverse is true for the electrode reverse polarity 33 + 66 % of the heat generation in the electrode side and about 33 % of the heat generation in the work piece side. So, amount of heat generated will be affecting the dilution as well as the cooling rate and that is why we select the polarity suitably.

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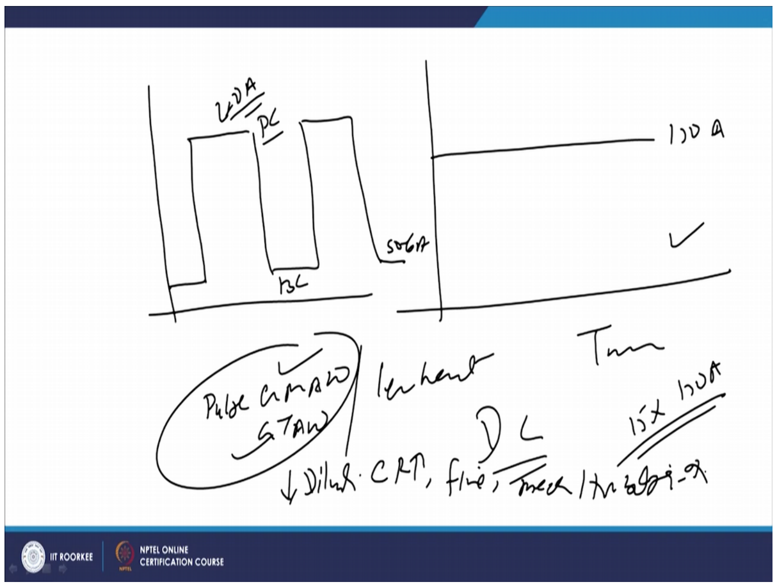

Another aspect related with this is the pulsation like normal case the current magnitude remains constant in the simple DC current as a function of time the correct magnitude remains constant. So, we may choose like 150 ampere current for depositing the bead on plate but if we use the pulsation and in case of the pulsing of the current between the background level and higher level and low level like this.

So, background level is maintained at about 25 to 30% of the peak current level and its magnitude should be such that arc is remain stable. So, this may be like 50 to 60 ampere and we may use like 200 ampere current for peak current. So, this is peak current this is back ground current. For same value of the average current we find that the heat generation of the heat input required in case of the pulsing for the similar kind of the bead on plate is less. So, basically the pulse variant of the GMAW or GTAW for depositing the bead on plate requires less heat as compared to the conventional welding wire constant magnitude is used.

So, if we use like a the voltage of 15 ampere and same average current value of 150 then we find that the heat input is more in case of the conventional gas metal arc welding or gas tungsten arc welding. Well in case of the pulse GMAW in pulse CATW heat input is less and that is why with the pulse varient of the GMA and GTAW that dilution is less cooling rate is high and the structure is in general fine and the mechanical and tribological properties are in general better.

So, these in turn help us in getting the much better quality of the weld surfacing. I will summarise this presentation, in this presentation basically I have talked about the few fundamental associated with weld surfacing which affect the quality or the performance of the weld surfacing. And these are basically the kind of protection that we provide to the weld pool during the bid on plate deposition the kind of cooling rate which is experienced by it and kind of dilution on which takes place during the weld surfacing. Thank you for your attention.