Failure Analysis & Prevention
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Lecture - 07
Fundamental Sources of Failures: Improper Manufacturing I

Hello I welcome you all in this presentation related with the subject Failure Analysis and Prevention. You know that we have talked about the failures caused by the deficient design; and likewise, there are many other fundamental sources of failure.

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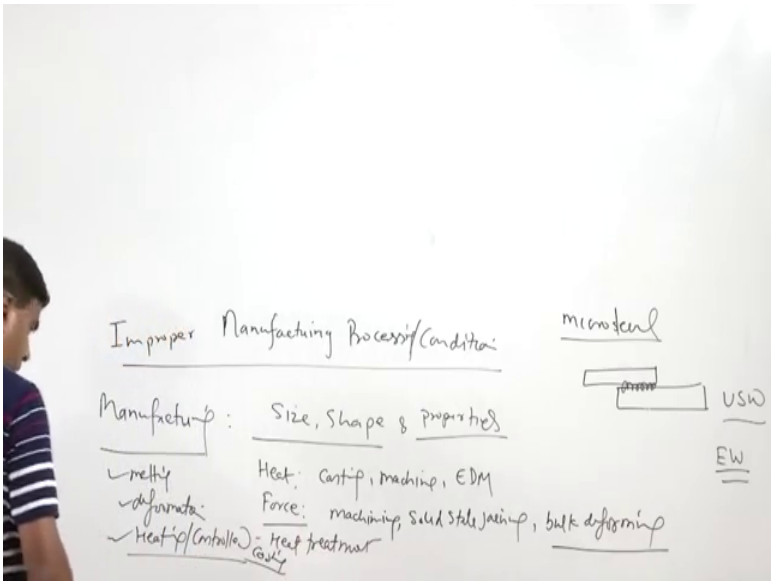

Today we will be talking about the failures occurring due to the improper manufacturing procedures or process or the conditions which are followed; so, we can say improper manufacturing conditions or the processing.

So we know that if metal is improperly processed during the manufacturing, then we may get the product of the desired and desired size and shape, but despite of the desired size and shape it may not it may not perform successfully as intended; and that may happen due to the various unfavourable features introduced in course of the manufacturing in the product; so we need to look into the factors related with the manufacturing, which result in the products and though the products which are prone to the failure due to the deficient or improper manufacturing. So, they are some general

factors and there was a few specific factors related with the manufacturing which lead to the failure of the components.

So, among the general factors for example, we have like the general procedure has not been specified properly or procedure has not been followed properly or procedure was modified means manufacturing procedure was modified in between inappropriately. So, these are some of the things which we will be talking in detail. So, we know that oh for manufacturing of a product what general approaches we use and; based on the approach that is being applied for a processing or manufacturing a metal to get the desired size and shape, the properties are affected; which may be favourable which may be unfavourable some of the special features also incorporated.

So, we know that manufacturing helps in achieving the desired size shape and set of the properties in the product. So, size and shape is primarily achieved through the use of the heat like in processes for heat; is used for melting in casting process also, heat is used for melting and ablution in the some of the machining processes like, laser machining and plasma arc machining, electron beam machining. So, heat is used for either melting or for ablution purposes electro discharge machining is also one of the examples, were material is removed in control way in order to remove the in order to get the desired size and shape by electric discharge machining.

Then use of the force so the force is used in various processes for example, we use machining, where the forces will help us to remove the chips from the raw material by the shearing action. So, this machining is one then like some of the solid state joining processes, wherein the macro and micro level deformation is achieved and then the bulk deformation processes like forming like rolling forging etcetera.

So, based on the approach being used for getting the desired size and shape; the properties of the end product are affected similarly like say um, when we when we use the force for bulk deformation purposes like in forging, rolling and a stress and processes. Similarly, sometimes the deformation at the micro level is also achieved in order to get the desired size and shape for example, when the components are welded using the spot welding processes not this ultrasonic welding processes ultrasonic welding process. So, micro level deformation at the interface leads to the metallic continuity from one end to another and which in turn helps in development of the join.

Similarly, the micro level deformation as also used in explosive welding process in order to get the metallurgical continuity and for developing the weld joints. So, these are some of the approaches where, either melting is carried out, or deformation is achieved or like in some of the processes we may apply just heating followed by controlled cooling.

So, this kind of the approach is used primarily in case of the heat treatment-based processes, where in desired microstructure is achieved in the metal systems for realising or for imparting the desired combination of the mechanical properties. So, heating deformation and the heating plus control cooling helps in achieving the desired microstructure in the heat treatment processes. So, as to achieve the desired set of the mechanical properties.

So, we know that we the heat is applied in various category of the processes whether it is casting, welding or machining. similarly the forces applied for a realising for achieving the deformation in the solid state joining processes; removing the unwanted material in machining and for achieving the bulk deformation, like in rolling forging and the stress and processes and we can say the micro level deformation is used in case of the ultrasonic welding explosion welding and little bit micro level deformation is also achieved in the diffusion bonding processes.

So, since the different metals are sensitive to the heat and pressure in to the different degrees; and that in turn affects the properties of the material which is produced. So, a proper fabrication or the manufacturing procedure needs to be established.

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So, whenever any metal is to be processed for the manufacturing purpose, manufacturing procedure is established. So, that manufacturing procedure maybe may be like for the casting purpose we have to melt the metal.

So, after the melting we have to perform the melted treatment; followed by we have to pour it in control way so pouring is to be done in a very controlled way thereafter we have to pouring into the mould is to be done thereafter solidification. After solidification we need to clean the casting. So, these are the kind of the sequence in which the metal will be processed to the different steps so up to what x up to at what degree the metal will be held after the melting?

How long it will be held before pouring? What will be added for the melt treatment? And at what temperature it will be added for the melt treatment purpose? At what temperature pouring is will be done? And how the solidification will be realised whether the directional solidification will be achieved? Or the solidification will proceed from the different directions followed by the cleaning whether the mechanical cleaning or the chemical cleaning is to be done. So, means there is a proper procedure for each of the manufacturing process.

Similarly, in case of the welding likes in fusion welding process what we need to do first of all edge preparation of the edge preparation is to be done. After the edge preparation the things need to be cleaned for all other impurities which are which may be there on

the same surfaces, and thereafter we have to select a suitable welding process edge preparation as for the requirement then the welding process, whether so as for the sensitivity of the metal for the heat as well as the environmental conditions atmospheric gases will be selecting suitable process, which may be like shielded metal arch welding it may be gas shielded arch welding or metal inert gas welding or; laser welding any suitable process which is selected which can help in developing the joint of the required characteristics.

So, after selection of the process next step is selection of the of the suitable process parameters process parameters and then execution of the welding. So, using this parameters the welding is performed; after the welding how, the chipping and cleaning will be done for removing the slag and other impurities and if any heat treatment is required in order to enhance the properties of the weld joint.

So, like these whether it is casting, welding, forming like a rolling forging restriction or machining for everything like we need to select some process, process parameters may be secondary treatment after the processing like finishing or heat treatment secondary treatment. So, each of these steps need to be carried out in very controlled conditions so that the product of the desired set of the properties can be achieved which can perform the intended function and which can serve the purpose.

Selection of inappropriate use of process parameters or non-clarity of the things to be done can always lead to the improper manufacturing. So, what is important; that first of all we need to understand what should have been done and whether that was followed or not must be investigated if subsequently the failure is occurring due to the inappropriate manufacturing.

So, the next step means the manufacturing a product by a particular process there will be certain steps which need to be followed and each step has to be carried out under the set of controlled conditions and these controlled conditions must be meticulously followed so that we can achieve the desired size and shape with the requisite set of the properties, but due to variety of regions we may not be able to follow the procedure which has been specified; and that leads to the deficiency in manufacturing and this deficiency in manufacturing can be in various forms, like one is unsuitable specification of the process

for manufacturing like whatever we have developed for example, in casting either our melting facility is improper for a given kind of the metal.

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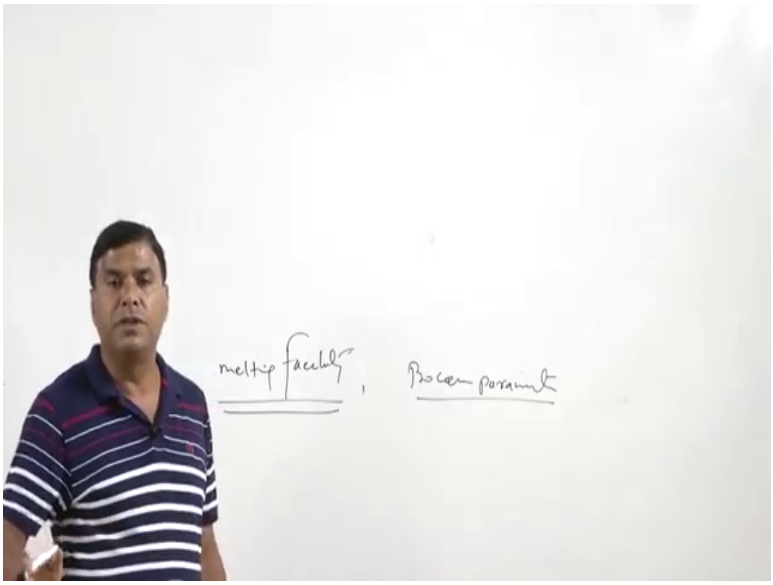

Like instead of a like for a electric furnaces used, electric resistance furnace is used or arch furnace is used or pit furnace is used.

So, so suitable heating or the melting facility has to be selected as for the material, which is to be processed; then thereafter inappropriate selection of the process parameters, means the conditions the temperature at which it is to be held how long it is to be held what is to be added in what amount for melt treatment purpose what will be the pouring temperature. So, that the proper fluidity during the casting can be achieved

So, likewise we can say a steps which to be followed which should be followed in course of the manufacturing if they have not been properly established, they are not suitable then it will lead to the improper manufacturing. So, what the first point is unsuitable is specification of manufacturing process or the procedure which has been procedure which has been established.

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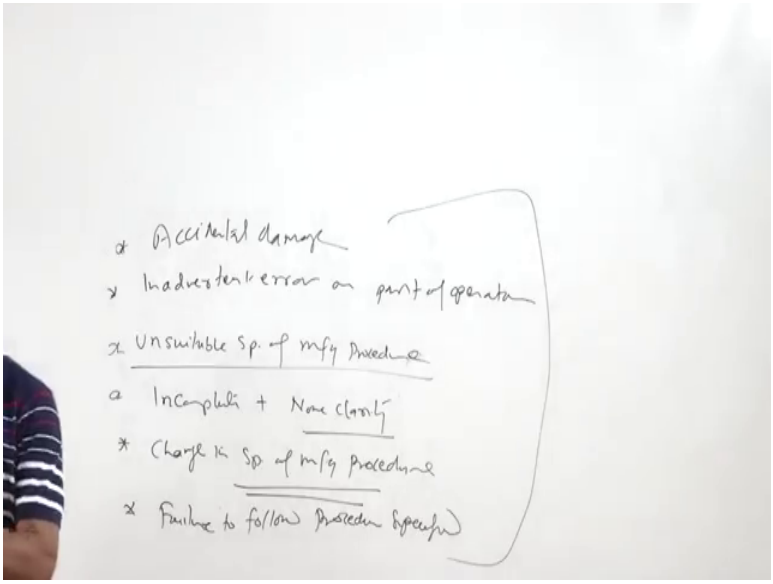

So, this is the first point even if the suitable manufacturing procedure has been developed, but it is not mentioned correctly. So, either incomplete details are there is non clarityor ambiguity exists in terms of the specifications which have been prepared.

So, incomplete manufacturing procedure specifications or non clarityor ambiguity in the specifications can also lead to the deficient manufacturing because the person who is implementing which is applying the manufacturing process at carrying out the different steps if we does not understand the steps to be followed properly then also it can lead to the deficient manufacturing; which can be in form of a like defective products or the products with the undesirable set of the mechanical properties and which in turn may be leading to the premature failure of the component during the service.

Sometimes the changes in a specification of manufacturing procedure; without proper evaluation of their effect. So, if this is done without proper consideration like for example, if earlier the GTAW was being used for welding of the titanium and without much of the considerations if the GMAW is shifted; then it may lead to the excessive higher heat input during the welding and increased heat affected zone and in proper size improper the properties of the weld metal can lead to premature failure of the weld joints.

Similarly, in case of the casting process if the molten metal is to be held at high temperature for a particular period of time. So, just for sake of saving the time if we are

reducing the period for which the molten metal is to be held for homogenised purpose; then it can lead to the inhomogeneity in the casting in terms of the chemical composition in terms of the microstructure and properties and so the premature failure can be increased if the molten metal is not held for homogenization purpose in the molten state for long enough. Similarly, after the grain refiner like say in the molten metal for refining the structure of the casting sometimes the grain refiners are added.

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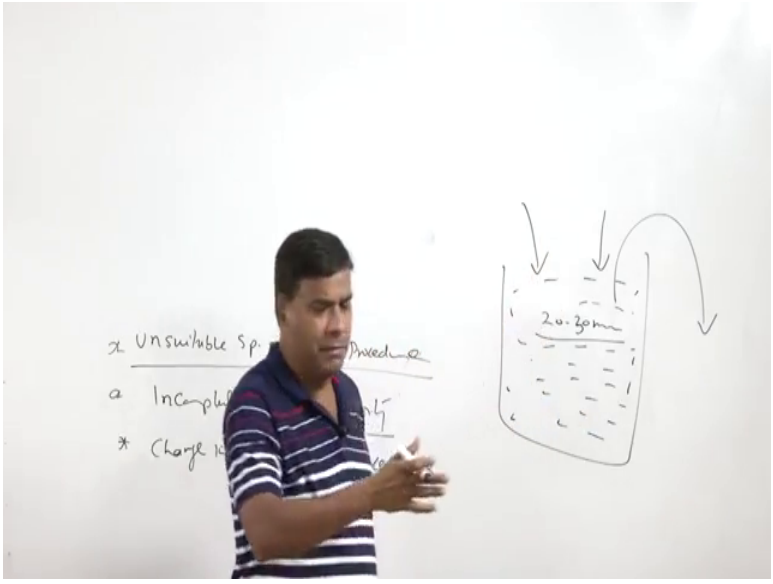

So, grain refiners after the addition of the grain refiners we must wait about 20 to 30 minutes; for getting the refiners to be activated and if that is not permitted; then despite of addition of the grain refiner in the molten metal when we produce the casting by pouring the molten metal earlier into the mould then it will lead to the coarse grain structure and so the poor mechanical properties

So, means each step of the manufacturing process whether it is casting welding forming has to be followed very carefully and very properly. there is another example like if the hot rolling is being carried out so mind the reduction in temperature or poor control over the temperature of the metal during the rolling can lead to the in reduced ductility and increased hardness which under the rolling conditions can show the surface cracks.

So, any change in the specifications without proper evolution can also lead to the deficient manufacturing. then here is another point failure to follow the procedure specified failure to follow the procedure specified means procedure is there, but we are

not in position to follow that; so iterations or modifications are done at the level of the operators so that can also have the undesirable things in the product which is being manufactured; whatever manufacturing processes used whether it is regard to the heat application or the temperature or cleaning or any other thing.

Then there is one more like inadvertent error on the part of on the part of the operator. So, unknowingly if the operator commit some error or mistake then that can also lead to the failure and then there is accidental damage. So, these are the these are the some of the generic points which has to be these are the some of the general points which are found to be the common causes of the failures due to the inappropriate manufacturing and according to the process these factors may be of the different type, but the points will be of this kind only or of these categories only.

So, it is very important that the manufacturing procedure is established properly and it is followed; otherwise we may have the product of the desired size and shape, but with the discontinuities in the properties which are unfavourable for the required performance of the product.

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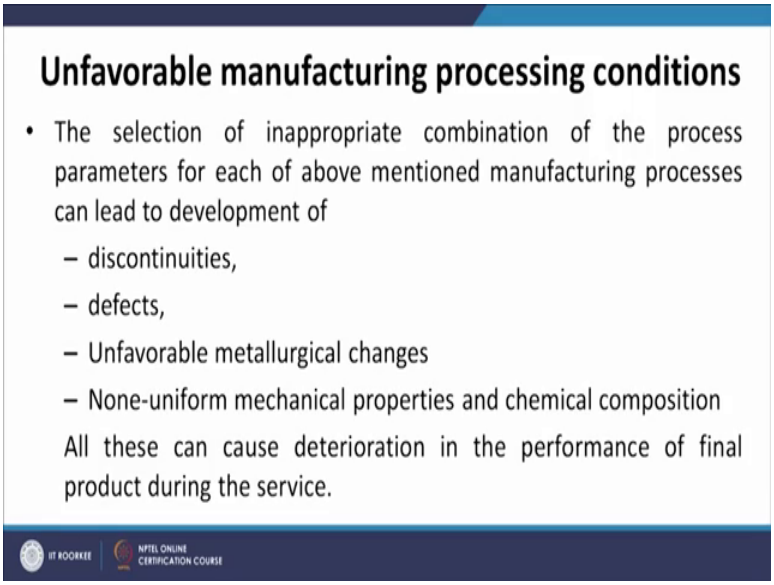

Now coming to the unfavourable manufacturing processes can and manufacturing processing and the conditions which are being used; so, if whether the just now I have explained that there can be different kind of general factors which can lead to the

improper or deficient manufacturing. And if that happens then it may appear in variety of forms. So, these forms are like the there may be discontinuities in the product.

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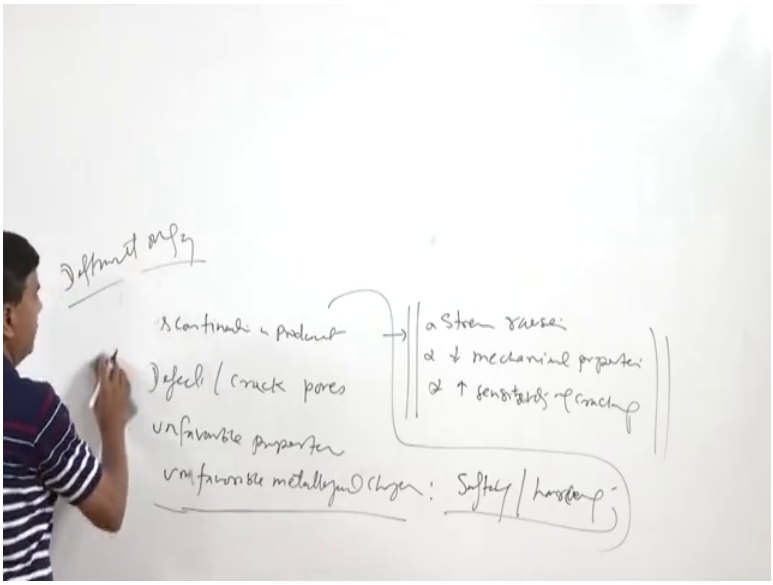

Which has been manufactured there may be large defects in form of cracks or pores or the blowholes etcetera or there may be unfavourable properties in the material unfavourable metallurgical, unfavourable, metallurgical changes. like unfavourable metallurgical changes frequently cause the undesirable set of the mechanical properties which may be in form of like the softening of the metals or unnecessarily unnecessary hardening of the metals; which may lead to the embrittlement and increased cracking tendency or reduced strength due to the softening.

So, if; so, these are some of the general undesirable features will be observed if the deficient manufacturing conditions are applied. And most of these will be either acting as stress razors in the component lowering the mechanical properties. So, they are load carrying capacity is also reduced or they may be leading to the increased sensitivity for cracking.

So, these are the some of the effects which will appear and these will promote the failure tendency of the component; if the deficient manufacturing is applied either intentionally or unintentionally. And as you know that if the stress razors then they will be acting as a source of weakness if the mechanical properties are reduced or unfavourable set of the metallurgical changes are brought in; then these will simply act as a sign of the weakness

of the source of the weakness and frequently these will trigger the nucleation and growth of crack under the external loading conditions. So, the premature failure is promoted.

Now will be saying that the manufacturing processes and the performance of the product the two are directly related.

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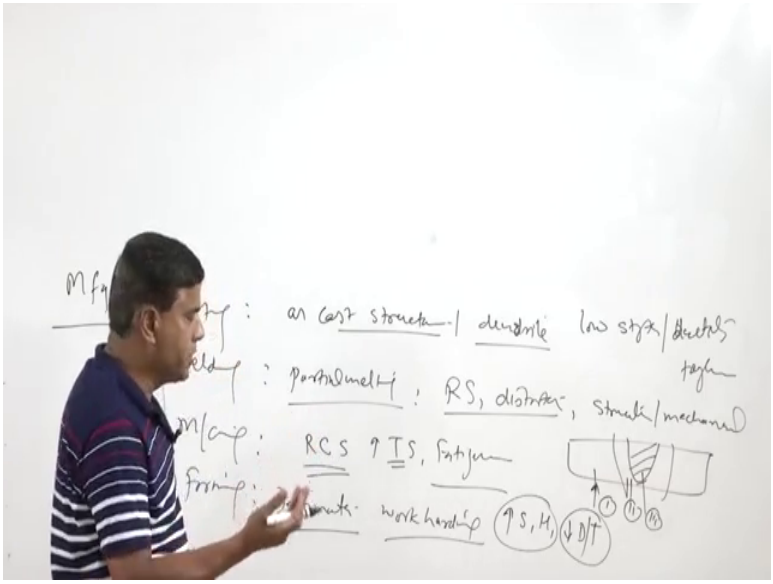

And so, based on the kind of manufacturing process which is used; like say if even if we go by the broader category of the manufacturing processes like casting, welding, machining and forming even if the same metal is processed by the different manufacturing process to get the desired size and shape will see will be finding the different mechanical properties or their different load carrying capacities.

So, different mechanical properties and different load carrying capacity is are observed why it happens so? That is what we will we seeing like whenever the product is made by the casting will be having the as cast structure which can simply observed through the presence of the dendrites in the cast component; and the cast components are generally low in strength, ductility, toughness and fatigue strength. So, all the in general mechanical properties are poor. You know in the case of welding mostly it is the fusion welding which is so it basically involves the partial melting.

And partial melting frequently lead to the development of the residual stresses and distortion tendencies; and apart from that the variability in structure and mechanical

properties, lot of variation right from the base metal like this is the weld joint so the weld joint will have the cast structure nearby zone will have the heat affected zone which will be modified of the influence of the heat and then the base metal. So, if base metal will have one type of structure heat affected zone another type and the weld metal are the third type.

So, lot of heterogeneity existing terms of the microstructure and mechanical properties and this will be leading to the lot of variation in mechanical properties. Sometimes weld is poorer or sometimes heat affected zone is poorer than the base metal in terms of the mechanical properties. machining you know in case of the machining where mechanical forces are applied for removing the material by shearing. So, one thin deformed layer is formed at the surface which leads to the residual compressive stresses, and presence of residual compressive stresses improves the tensile strength improves the fatigue resistance of the material; provided this the machine component is smoothen properly for the presence of the irregularities.

Similarly, in case of the forming where mostly the deformation is used for achieving the desired size and shape; and this kind of deformation is mostly accompanied by the work hardening and work hardening if it is done under the cold conditions, increases the strength increases the hardness, but certainly at the cast of the ductility and the toughness.

So, ductility and toughness both are decreased while the strength and hardness improve and if the deformation is carried out at high temperature then of course, the size and shape is achieved without much compromise in terms of the strength and ductility because the strengthening mechanism in that case becomes grain refinements of control heating and the mechanical deformation, which is also termed as thermo mechanical working of the metal helps in realising the properties without much adverse effect while changing the size and shape of the material.

So, as far the manufacturing process being applied the different structural changes are brought in to the metal being processed and those structural changes lead to the variety of the mechanical properties in the manufactured product and therefore, we can say that manufacturing processes being applied, affect the mechanical properties of the

component the same material is processed also even that we can find the lot of variation in mechanical properties.

So now I will summarise this presentation, in this presentation I have talked about what are the fundamental approaches which are used in manufacturing and what are the general sources related with the deficient manufacturing which frequently cause ah, the presence of the defect and discontinuities in the products and what are the general ways by which manufacturing processes can affect the mechanical properties of the component.

Thank you for your attention.