HOLE BASIS SYSTEM IN INTERCHANGEABILITY, LIMITS, AND FITS IN QUALITY ASSURANCE IN THE PRODUCTION PROCESS OF MANUFACTURING

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Abstract

Quality assurance refers to the ability of whatever that is produced to work towards the satisfaction of the prescribed standards of design, and in this case the manufacture of machine mating parts or for any other mechanism to be free from doubt. This assures the designers to the belief in the ability of the performance of the machines or mechanisms, as they have sureness of their abilities and can speak authoritatively of whatever that has been produced. This is as in any hole basis system of manufacture. There is the consideration of producing the holes first by using the standard tools of drilling, boring, and reaming before the production of the shafts. This is however quite different from the shaft basis system which entails the production of the shaft before the holes can be made. Should the shaft be made first and the dimensions not as accurate as it could be made to the desired dimensions; hence, there are no standard tools to correct the hole of the mating part to the prescribed design. Then, of course, the system of limits and tolerances are therefore envisaged for interchangeability, in the course of the assembly of the machine mating parts or mechanisms. This is in view to attaining the right quality, with quality control necessary for the achievement of the required standards in manufacturing. This then involves the inspection and sorting out of the corresponding types of fits. These corresponding types of fits are clearance fits, transition fits, and interference fits. Thus, quality assurance offers us the privilege of the round peg in the round hole of a clearance fit, remaining a clearance fit; a transition fit, remaining a transition fit; and an interference fit, remaining an interference fit. However, the system of limits and fits have offered the production process a manufacturing process which is a lee-way in metal cutting process whereby the art of metal cutting process is in the removal of excess metal of a part by machining. This can be done through the various machining processes of the lathe machine, the drilling machine, and as well as the milling machine. Other machines are the use of the shaping machine, the planning machine, and the super finishing machine of the grinding wheels of the grinding machines.

A. Introduction

The term quality of a product refers to the degree of the excellence of the product, which although is a relative term, could convey different meaning to different people. Then quality control is thus a system which is determined by the idea of a phenomenon, suggesting how often and how to inspect by checking. It however helps in corrective action, as a feedback mechanism, and which explores the issues arising from poor quality product, and with the product quality of course consisting of varied number of elements, as shapes, sizes, its finishes. These are then the characteristics of quality, which are always specified in parts or manufacturing drawings.

Then, the term quality control of a material or product is in its conformity to the products drawings and specifications, and which is outdated for it does not meet the quality control objectives. This is because the product quality may conform to the set drawings, together with the specifications, but may not satisfactorily serve the purpose of its design. It is based on this, that (Rao, 2007) defined the quality of a product, as that totality of the features and the characteristics of any product or service, that has its ability in the satisfaction of a given need. This, as today’s quality thus means the ability to serve the purpose of the product’s reliability with barest minimum of maintenance. Hence, this is as the advent of quality movement in many countries has accepted in the recent past, and all over the world this is cited as the definition of the term, quality.

Inspection and Quality Control.

The end products of any particular production process could suffer from any inherent
variability in the dimensions, in the colour, in the chemical composition, or in the physical properties. Thus, (Lilly, 2006) defined quality control as the quality maintenance standard being specified to contain the variability, which is within certain defined limits. Hence, quality standards for any manufactured artifact can be dictated by fulfilling these requirements. These are the effectiveness functionality of the completed component, and the cost of its production, with each product life estimation. The rest are the components interchangeability and the assembling with ease, of the product appearance and the feel of the use of the end-product.

However, (Gopalakrishna & Rao, 2017) described quality as a relative term, and as a practical approach, in which quality levels can be categorised as the workmanship standard, and of which to maintain quality, stage inspection is an effective tool. Inspection is thus a method used to check materials or parts that are necessary for the production of a product. This is with a view to seeing if the product meets the desired standards of quality for the next production process, and then with a view to checking if the product, upon completion, meets the required customer specification and satisfaction. The process of inspection usually involves the measurement of the materials, the parts, or the completed product by various methods and with it being compared with the results of the relevant standards that is to be adjudged if they can be acceptable or not.

Hence, inspection helps in the selection of the parts which will of course function very satisfactorily when in use in its life time. Thus, it is of note that the reason for inspection, or its philosophy is only to prevent, and not to remedy. It is in this relation to customers' satisfaction that (Jain, 2014) refers to quality in manufacturing as how well the process of production meets the design specifications, and in which is related to its different features and the very properties of the given product.

The Various Methods of Inspection

The various methods of inspection are of two types, which are total inspection and sampling inspection. Total inspection consists of measuring each quality of a product lot and hence approving of it. The sampling inspection consists of measuring some samples taken of each product lot for examination, which is however based on the approving of the lot to be based on the result of the inspection. Thus, the number of samples in sampling inspection, for inspection and acceptability of the judgment criteria are however calculated and is determined by the use of the statistical methods. One of such methods is the selection taking into full account of the importance of each of the product quality characteristics, and as well as the economic aspect of inspection.

The three (3) basic areas of inspection

Receiving inspection. In receiving inspection, also known as acceptance inspection, the incoming material, parts, and as well partially fabricated items are carried out at the production site. The purpose of receiving inspection therefore is to essentially check whether the purchased parts can conform to quality characteristics given on the drawings and are in order. Thus, a proper receiving inspection will always prevent any waste of time, and as well as loss of money in the production process. It helps by identifying non-conformity items that could occur at the receiving stage itself.

Process inspection. In the process inspection, the delivered item undergoes one form of processing to another from the delivered items. Hence, the carrying out of these inspection processes properly, will help to make corrections before any rejections are produced, and thus keep the possibility of a rework at a level low enough in many of the cases, and especially in dimensional control situations.

Final inspection. In the final inspection process, also known as the delivery inspection, the finished work is inspected in order to ensure that this is the right quality of delivered product. Hence, the product is evaluated in this particular type of inspection, as this is for the evaluation of the product in its appearance, and in its performance. This is thus in keeping with the customer's requirements in view.
B. Quality control

Quality control (Q.C) refers to a system in which the customer’s requirements are met by the production of a high quality product by using the most economical means. Hence, this is the totality of a company’s activities as a whole; which then means to develop, to design, to produce, to inspect, and to sell products of high quality. However, this is therefore with a view to providing long lasting satisfaction to customers.

Note that inspection is just a part of quality control measures in determining if the supplied raw materials and its finished product are acceptable, with quality control being a broader aspect which finds solution in order to reduce the rejections, and as well defective products. In essence therefore, the need for inspection is reduced, when the control becomes better, as it is being observed. Thus, (Nwala, 2003) stated that quality control is a management technique for making sure that all the products have the right quality for the satisfaction of the customer, and at which must be at the minimum cost and a maximum profit for the given quality.

This is with the basic idea that quality control is to prevent defective products elimination. Thus, quality control offers us the opportunity of not allowing the production of defective product items at all, through its quality control measures. Hence, should the production of defective items occur, quality control ensures corrective action to be taken in order to prevent its future occurrence. Therefore, quality control is economically very objective in its purpose, as well as dynamic in all its operations, and even helpful in its treatment whenever it is employed. It suggests when to inspect, and also how often to inspect, and furthermore how it must be inspected.

Total quality control. The total quality control is a concept given to a system, of which all in house departments of an organization, all together produces, and as well sells products of high quality, in order to satisfy their customers, with the lowest possible price, and the fastest possible speed. All departments must therefore include the development, the production, and even the sales in order to provide the customer with the highest quality product possible. Hence, staff members must produce very high quality products at the upstream source of production with the highest efficiency possible. Therefore, all employees should perform their own job diligently, in order to promote the best quality control, by working towards the single goal of satisfying the customer. Thus, in order to provide the necessary satisfaction to the customers, and also to promote that same function, requires that each department clarifies what kind of work it must carry out. This is what is often referred to as the activities of the total quality control or world-wide quality control organizations.

Statistical quality control. The function of a quality control system is to perform inspection, as well as testing, and also analysis in judging whether or not the quality of each of its products is always at par with the laid down quality standard. This is because a 100% inspection of parts or production process is not feasible and practicable, not possible in any continuous production. Hence, certain statistical techniques must be devised, in order to evaluate machines, materials, and processes. This is by observing the capabilities and the trends in the variations, so as to solve quality control problems, by the continual analysis, and as well as predictions which hence is to be made to control the desired quality.

The production, the manufacturing, and the assembly process

Machining is one of the processes and methods of shaping used in the production process of identical items by the removal of metal components. Higgins, (2014) described machining as a metal cutting process necessary to bring about metal items to the desired shape. There are many metal shaping procedures or processes of metal cutting. However, (khanna, 1998) described metal cutting as the procedure of changing the shape of the raw metal into a finished products by plastic deformations. This involves a series of steps of metal removal in transforming a blank from its original shape by just changing its shapes by metal cutting operations.

Manufacturing engineering is the process that is required in making parts and to
assemble them into machines and mechanisms. Therefore, this is a process of the production of machines and mechanisms; and which consists of operations which are complex for the making of the blanks, and machining of the blanks, which are called stocks in order to obtain the required finished items. Thereafter, the assembling of the various units and certain separate parts of it into machines and mechanisms are accomplished.

The production process as accomplished in the production plant, is the sum total of separate processes that are involved in this conversion. Hence, the production process of any material work piece, rather involves the transformation of a piece of blank material or its raw pieces from its state of originality to a state of finish by the mere changing of its shape and the metal properties in a series of steps. Then, at the completion of the processes, and when no further changes are to be made; it is therefore known as the finished piece, finished part, or finished product.

**The Production Process**

The sharpening of weapons by stones that have grinding properties, was one of the ways the primitive ancient times accomplished their production process. They first held the cutting tools in the working position, which was by hand; and they secured it later to a handle by withes or animal sinews. This was the achievement of that time as it was with the application of the rolling stone, which turns out to be the prototype of the modern tool grinder of today’s technology. Then later, the employment of the rotary motion was for the making of the ceramic ware, and of late for the production of raw articles such as wood, bone, and then finally that of metals.

However, mechanisms were used for the drilling of the material being worked with, along with the devices for the transmission of motion to the cutting tool. Thus, the primitive lathe prototype was the bow, which then rotated the work; and which was by means of the bow string, with however the flint tool always being rotated by hand. This was the simplest turning tool type that was then being developed and which of course was gradual.

The production process also includes not only the various processes for the direct changing of the shapes, as well as the properties of the material in the parts to be produced, and assembling them, of which is into machines and mechanisms, but it also involves all the auxiliary processes as well. The auxiliaries include all the supporting activities that will enable the production process to, as whole, be accomplished. These include inter-shop material and part handling, and the manufacture of cutting tools and its sharpening. It however includes equipment maintenance and its repair, with high quality inspection, etc. in assembly.

**The Manufacturing Process**

This is the processes that is required in making parts and later assembling them in the form of machines and mechanisms. The production of machines and mechanisms process then consists of multi-complex operations for the making of the blanks, and machining them (the blanks), in order to obtain the desired finished parts or products. Thereafter, assembling them, that is the various units, and of course certain separate parts are put together in to what is now known as machines or even mechanisms. This involved the conversion of the raw materials and semi-fabricated products into blanks, finished parts of units and mechanisms; of which is the sum total of production and manufacturing processes.

Hence, the manufacturing process is that part of the production process that is directly concerned with the dimensional changes of shapes, and as well as the blank material properties. Therefore, the manufacturing process consists of the operations which are accomplished in a definite sequence.

**The Assembly Process**

This is that part of the production process, which is concerned directly with the consecutive joining of the finished parts into assembly units. Thereafter, they are called complete machines or mechanisms of high quality that meets standard specifications of manufacturing.

**Machining Process**

Machining is a process of production as well as manufacturing that gives the desired shape to a given material, and which is by removing the unwanted extra materials, always in the form of chips by cutting. Thus, machining is a metal working operations which basically are mainly directed towards the impartation of the desired form, as it is generally of dimensions to metallic raw materials, which is geared towards the production of finished article or
component (Banjo, 1979). This then requires the employment of different machine tools to cut off the undesired portions of any metal casting, so as to obtain a final component which is with the required shape and component dimensions.

However, the cutting tool material is far harder and also sharper and stronger than the material of which it is to cut. Parmar (2003) named the machines involved in these processes, and which are commonly employed as the turning or lathe machine, milling machine, drilling machine, as well as the shaping machine, the boring machine, and the reaming machine. It will be recalled that the lathe machines and milling machines were both employed in the fifteenth and sixteenth centuries in connection with watch making. However, most of these processes were later introduced into the high volume industries for making steam engine parts, in their present form in the nineteenth century, which in the present century has come of age.

All materials cannot be machined with the same ease, and as such, as a rule of thumb, harder materials with high tensile strength are by far more difficult to machine. Likewise, the very soft materials are even more troublesome to machine, as there is the occurrence of seizures between the tool and the work piece material. Hence, there is a specific hardness range above and below which machining efficiencies decreases.

C. The limit system and surface finish interchangeability in quality assurance

Interchangeability.

Khurmi & Gupta (2009) has described interchangeability as the term employed for any mass production of identical items, within the limits that are prescribed. Thus, a little consideration will eventually show that a lot of time is required in order to maintain the sizes of the part within the desired close range or accuracy; and which even at that, there may be some small variations. The variations are within certain limits, which means that all other parts of the equivalent size will then equally be fit for the operations of which the machines and mechanisms are meant and designed for.

This therefore means that to get the required fitting, there must be certain variations, which must be recognized and also allowed in the mating parts. Therefore, for a considerable savings in the case of production, requires the selection at random in order to facilitate a large number of parts for any assembly. Thus the limit system is designed in order to control the size of any finished part, which will then give due allowance, arising from any errors for any interchangeability.

However, an assembly is usually made of two parts known as the male and female. The one that enters the other is regarded as the enveloped surface or the shaft for any cylindrical part known as the male. Then, the other, in which one enters is regarded as the enveloping surface or the hole for any cylindrical parts known as the female. It worthy of note that the use of the term shaft is to designate any external dimension of a part, and not always the diameter of a circular shaft. Furthermore, the term hole is as well used to designate any internal dimension of a part, and not always the diameter of a circular hole

The important terms that are being used in the limit system.

In any interchangeable system, the following terms are in the limit system, which are very important from the point of view of this subject.

The nominal size. This is the size of a part that is specified in any design drawing for the sake of convenience, as an example, Ø50mm.

The basic size. This is the size of a part, of which all the limits of variations are specified; i.e. the tolerances in order to get the final dimensions of two mating parts. Usually, the nominal size and also the basic size are always the same.

The actual size. This is the actual measured dimension of the part, with the difference between the basic size and the actual, not exceeding a certain limit. This will thus otherwise interfere with the mating parts interchangeability.

The limits of sizes. There are only two permissible extreme sizes for the dimensioning of a part, with the largest or maximum permissible dimension size known as the high or the maximum or the upper limit. Then, the lower or the minimum permissible size is called the
minimum limit or the lower limit.

Allowance. Allowance is just the difference between the mating parts basic dimensions, and which may be positive or negative, as the case may be. Whereas, when the size of the shaft is less than the size of the hole; it is known as positive allowance: while, when the size of the shaft is greater than the size of the hole; it is called a negative allowance.

**Tolerance.** Tolerance is referred to as the difference between the upper limit and the lower limit of any dimensioned part, or the permissible maximum dimension variations. Thus, any tolerance may be unilateral or may be bilateral. However, when all the dimensions of the tolerance are allowed on one side of that of the nominal size, for example, $50^{+0.000} - 0.004$, then, it is a unilateral system of tolerance. This unilateral system is mostly employed in the industries because it permits the changing of the value of the tolerance limits while, it still retains the same type of fit allowable. Also, when the tolerance is only allowed on the both sides of the nominal size, for example, $50^{+0.000} - 0.002$, then, it is a bilateral tolerance system; and in which case $+0.000$ is the upper limit, and $-0.002$ is the lower limit.

**Tolerance zone.** This is a straight line corresponding to a basic size; with the measurement of the deviation from the line: which can be the upper deviation, or lower deviation.

**The upper deviation.** The upper deviation is the algebraic difference, that is between that maximum limit and the basic size. ES (Ecart Superior) is the symbol representing the upper deviation of a hole, while es is the symbol for a shaft.

**The lower deviation.** The lower deviation is the algebraic difference that is between that of the minimum limit and that of the basic size. EI (Ecart Inferior) is the symbol that represents the lower deviation of a hole, while ei, represents that of a shaft.

**Actual deviation.** Actual deviation represents the algebraic difference that is between an actual size and that of the corresponding basic size.

**Mean deviation.** Mean deviation represents the arithmetic mean between the upper and that of the lower deviations.

**Fundamental deviation.** This is usually one of the two dimensions which is always conveniently chosen in order to define the tolerance position zone in its relation to the zero line. Hence in an example of $50^{+0.035} - 0.025$, therefore, the basic size is 50mm, with upper deviation as 0.035 and that of the lower deviation as 0.025. thus, the maximum limit size = $50+0.035 = 50.035$mm; while the minimum limit size = $50-0.025 = 49.975$. therefore, since the tolerance is that difference between the maximum limit size. Then, it however means that this tolerance is $50.035 - 49.975 = 0.06$mm in this case.

**Fits.**

This is the degree of tightness or looseness, that is between the two mating parts, referred to as the fit of the parts. However, the nature of the fits is always characterized by the degree of the presence of the clearance and the interference size. The fits are often classified as follows; the clearance fit, the interference fit, and the transition fit.

**The clearance fit.** The clearance fit is known by the amount in which the actual size of any given shaft is usually lower than the actual size of the mating hole in the assembly. This means that the clearance is the difference between that of the sizes of the hole and that of the sizes of the shaft, before they are assembled; and in which case, it is always positive. Always, in this type of assembly therefore, the limits of the sizes are so selected that there is clearance between the mating parts. Also, in a clearance fit, the tolerance zone of the hole is usually entirely above that of the tolerance zone of that of the shaft.

It must however be noted that in a clearance fit, the difference that is between the minimum size of the hole and that of the maximum size of the shaft is called the minimum clearance. Then, the difference that is between the maximum size of the hole and that of the minimum size of the shaft is known as maximum clearance. The various types of clearance fit can be of the slide fit, the running fit, the slack running fit, and as well as the loose running fit.
The interference fit. An interference is always the amount at which the actual size of a shaft is being larger than that of the actual finished size of the mating hole in an assembly of the system of fits. This however means that the interference is the arithmetic difference, between the sizes of the hole and that of the sizes of the shaft, before it could be assembled, and in which case must be negative. In this type of fit, the sizes of the limits for the parts must be so selected for any interference to occur between them.

It must always however be noted that in an interference fit, the tolerance zone of that of the hole must entirely lie below that of the shaft. Thus, in any interference fit, the minimum size of that of the shaft is called the minimum interference. Then, that of the difference between that of the minimum size of the hole and that of the maximum size of that of the shaft is known as the maximum interference. Hence, the interference fits may be that of the shrink fit type, heavy drive fit type, and the light, as well as drive fit types.

The transition fit. In the transition type of fit, the size limits for each of the various mating parts are selected such that neither that of a clearance fit nor an interference fit may then occur. This thus depends upon that of the actual size of the mating parts, as it must as well be noted that in any transition fit, that of the tolerance zones of those of the holes and those of the shafts must overlap. The transition fit types are that of the force fit type, tight fit type, and the push fit type.

The basic of the limit system.
The basic system of limits is of two types, namely the hole basis system and the shaft basis system.

The shaft basis system. This is when the shaft is kept constant as a member, and which means that the upper deviation of that of the shaft is kept at zero. Then, the different fits are therefore obtained by the variations of the hole sizes. This system of which the shaft is kept constant and the hole thereby being varied is called the shaft basis system although it is never preferred.

The hole basis system. The hole basis system is when the hole is kept constant as a member, which means that the hole deviation is kept at zero, with the different fits being obtained by the variation of the sizes of the shaft. Hence, therefore this system is then referred to as the hole basis system.

The hole basis system is often preferred in manufacturing than that of the shaft basis system. This is because the production of the holes is by the standard tools of the drilling, reaming, etc. and which its sizes cannot be easily adjusted. Then, the shaft size which goes into the hole can just be adjusted to get to the desired size by the operations of turning or grinding manipulations in order to get the actual size.

The Surface Finish
Surface finishes are produced by different machining operations, of which are that of the turning or lathe machines, the milling machines, and the shaping machines. Others are the planning machines, the grinding and super finishing machines, as all of these offer different characteristics; with a marked variation in which they are compared to each other. The variations can however be adjudged by their degree of smoothness; as a surface that is produced by super finishing is adjudged the smoothest, while that of that of the planning as the roughest.

However, it is absolutely necessary to describe the surface finish in quantitative terms in the assembly of two mating parts. Therefore, this is with a measure of the micro-irregularities of the surface finish, which is thus expressed in microns. Hence, in order for it to prevent stress concentrations, and for its proper finishing; it must therefore become vary necessary for the avoidance of surface roughness, or for it to have surface roughness.

Surface Roughness and Measurement
There are several ways in which surface roughness can be expressed, but however, there are these two basic types which are therefore the most commonly used. These are: the
centre line average method, also called the (CLA) method; and the root mean square method, also called the (RMS) method.

D. Conclusion

The preference of the hole basis system over that of the shaft basis system allows for a system of interchangeability in the assembly of mating parts. This offers the advantage of varying the shafts to suit any manufactured hole, which the hole is often achieved by standard tools of drilling, boring, and reaming. Thus, it is easier to vary the external dimensions of the shafts than the internal dimensions of the holes. This is the very reason for the singular objective of the hole basis system of interchangeability of system called limits and fits.

Limits and fits, as well, offer the requirements for the various assemblies of machine parts or mechanisms; in order to obtain the desired fits in any assembly. This is why a system of fits, which are the clearance fit, the interference fit, and the transition fits can be obtained as it therefore offers a greater deal of many varieties in the production of machine parts or any mechanism assembly. Thus, in any system of limits and fits, a certain tolerance is permitted for the optimal performance of a machine or mechanism assembly.

Hence, this is the quality assurance that is necessary to be offered to customers or consumers, the desired best value for their money. Thus, a customer that required a transition fit for his bearings and shaft and housing cannot be offered the same for that of piston and rings and the engine cylinder that requires clearance fit. This is just the basis for which this paper is written, and viewed from the point of the production process in the manufacture of machine and mechanism parts, which entails the adherence to the prescribed standards in machining, before any assembly can be carried out.

Recommendations

This research offers us a survey of the quality assurance in the production process of the manufacture of machine or mechanism components through machining. It therefore makes the following recommendations.

The hole basis system is the most preferred system of machine or mechanism manufacture by machining, as this entails the making of holes with standard tool of reaming, boring, and even grinding. In this case the shaft is being varied to suit any type of fit that is then required.

In the assembly of parts for machines and mechanisms, the required fit must however be considered first, in order to allow for optimum performance of the machine parts or mechanism parts members. This is because a clearance fit utilized for a transition fit, indicates that the part is already won before its use.

The tolerance of the limit of the fits for which any machine or mechanism member are to be made must be adhered to in order for the machining of parts to have the required value.

References


