COMPREHENSIVE QUALITY MANAGEMENT THROUGH ADVANCED NONDESTRUCTIVE TESTING TECHNIQUES FOR RELIABLE PERFORMANCE OF WELDED COMPONENTS

by
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INTRODUCTION

Welding Technology is an essential ingredient of the industrial world. It is impossible to imagine the industrial scenario without this technology. While it is necessary to use the already established welding technology in the conventional materials and components with more and more stringent control on quality and reliability, it is also necessary that conventional and newer welding technologies are used in newer materials and in newer component designs that are undertaken for newer applications, and for improving the economy. A good welding technology and practice must ensure that, whatever may be the innovations introduced, there must not be any sacrifice on safety and reliability that are expected from the components. All the efforts made to design a good weld and to fabricate one may simply be wasted if it is not ascertained and known beforehand that the joint is indeed fit for the purpose. Management of weld quality should be comprehensive, covering design, fabrication, use and discard.

In order to achieve comprehensive quality management, multidisciplinary efforts are needed and wide ranging R & D activities must be initiated. An important philosophy preached and adhered to by the nuclear and space industries, particularly in India, is that cost-effectiveness and quality are inseparable partners for obtaining long term benefits from any industrial endeavor. The motivation behind this philosophy is the widespread and mandatory need for comprehensive quality management.

DYNAMIC NATURE OF CODES AND STANDARDS

It is important to recognize that codes and standards are evolved by multidisciplinary inputs from experts having rich experiences and insight in the particular field. Codes, Standards and Specifications are constantly evolving in line with the progress and developments in the industry. At any point of time, the codes and standards reflect the level of technological expertise available. However, there is always a gap between the codes and standards and the level of available technology. The technology may be at a higher level than that implied in a standard. However, it may not be proven. Only proven technology (materials, manufacturing process, inspection techniques, inservice inspection) gets incorporated into standards and codes so as to benefit a given industry or industries. The user company can always ask for higher level of technology from the service provider available at that time, but not included in the codes and standards, if it is felt that this is necessary for enhanced quality and reliability (even if this may entail additional costs). But for that, it must ensure that a special code/standard is made specific to the application at hand.

It is essential to appreciate that updating of specifications is an essential feature of quality management in any system. Specifications are modified to take care of deficiencies noticed in the service or to effect the improvements called upon by advances in technology. As the level of technology improves, to remain competitive in business as well as to ensure safe and reliable performance of components, it is essential that design, manufacturing and inspection specifications are updated.

The realistic engineering inspection of some of the critical welded components for enhanced reliability is often not possible with the present NDT standards. The standards specify the use of artificial defects. Strictly speaking, use of artificial defects to simulate the natural defects is basically invalid and illusory. This observation is based on the fact that the equivalence of a natural defect and an artificial defect is not achievable. Again, the standards are often silent on the microstructure of the parent metals and the weld metals that may significantly influence the defect detection capability of a NDT technique. An important example is the ultrasonic testing of large grained and textured austenitic stainless steel weldments. In such cases, sophisticated methods often are required to extract desired information from the noise signals. Thus standards are required on advanced signal and image analysis, pattern and cluster analysis and artificial intelligence to give clear and reliable evaluation of defects in welded components made of thick austenitic stainless steel materials.

The summary of the above arguments and descriptions is aimed to convey that no standard is static, not even ISO-9000. The survival of the industry depends on evolution and improvement. This concept, well known as Deming (the quality Guru) rule, has emphasised that quality improvement and not the present quality should be the end objective.

GOOD ENGINEERING PRACTICES FOR ENHANCED RELIABILITY

The design, manufacture and construction should employ proven techniques and it should be possible to conduct such analysis of the design as may be necessary for the purpose of demonstrating adequate integrity at any specified time throughout plant life.

Every effort should be made in the design, manufacture, construction and operation to avoid the occurrence of defects in the structure. Analyses should be provided to demonstrate the following at any specified time in the life of the plant : (a) that an adequate margin exists between the capability of defect detecting equipment and dangerous defects, and (b) where defects are detected, they can be accepted or an adequate repair can be made. All materials employed in the manufacture and construction should be demonstrated to be suitable in all respects for the purpose of enabling an adequate design to be constructed, operated, inspected and maintained at all specific times throughout the life of the component.

The important fabrication rules are the following : (a) Use of high standards of materials, (b) Use of high quality welding during all the stages of manufacture supported by a Quality Assurance Programme which ensures full approval of procedures and provides verification of compliance with the procedures and practices and (c) Use of pre-service and in-service inspections to detect subcritical defects which have the potential for developing into critical sizes in future and leading to failures. The three main areas of materials, welding and inspection assessments should be considered carefully to achieve high reliability.

During manufacture, inspection has three principal objectives : (a) to provide an assurance that there are no unacceptable defects by which it is ensured that the manufacturer has satisfied the standard required in the contract specification, (b) to provide assurance that subsequent inspections can be carried out, and (c) to provide assurance that no defects are present in the completed component which could be of safety concern. To meet these objectives, components are subjected to a number of inspections during fabrication. For example, inspection of cast austenitic steel is difficult due to the coarse, columnar grains and is often limited to relatively thin surface layers. As the various welds joints are completed, inspections are carried out to ensure that no significant defects are present and that the required quality standards have been met. Finally, after stress relief heat treatment (where appropriate), the welds are reinspected to confirm that no defects of concern to safety and reliability are present. Subsequently, duri g service, inspections are carried out to find : (a) new defects, which may include small sized pre-existing defects that have grown and become detectable as a result of service exposure, and (b) defects that have grown in service from below the reporting threshold.

THE ROLE OF COMPREHENSIVE QUALITY MANAGEMENT

Strict control, documentation and updating of data in the following areas are mandatory for CQM : (a) Choice of raw materials, (b) Processes, (c) Final Product, (d) Marketing, (e) Services (with respect to both Spatial Efficiency and Temporal Efficiency), (f) Product Support; Customer Support, (g) Product Upgradation, (h) Education to the customer about the product or the service, (i) Gradual phasing-out of any product and its related services, (j) Gradual re-introduction of the new product, (k) the beginning of the next equivalent cycle leading to a better product or service.

More than the sum of its parts

Each and every step of this cycle consists of smaller stages, whose total is more than the sum of their individual parts, and it is this total that constitutes CQM. These stages can be identified with the rungs of a ladder towards CQM, on a scale of 10, as shown in **Fig. 1**. In this figure, the preliminary stages are at the bottom of the scale, with the more advanced and final stages at the top. The figure has been envisaged keeping in mind a Company that is moderately large with several areas of product development

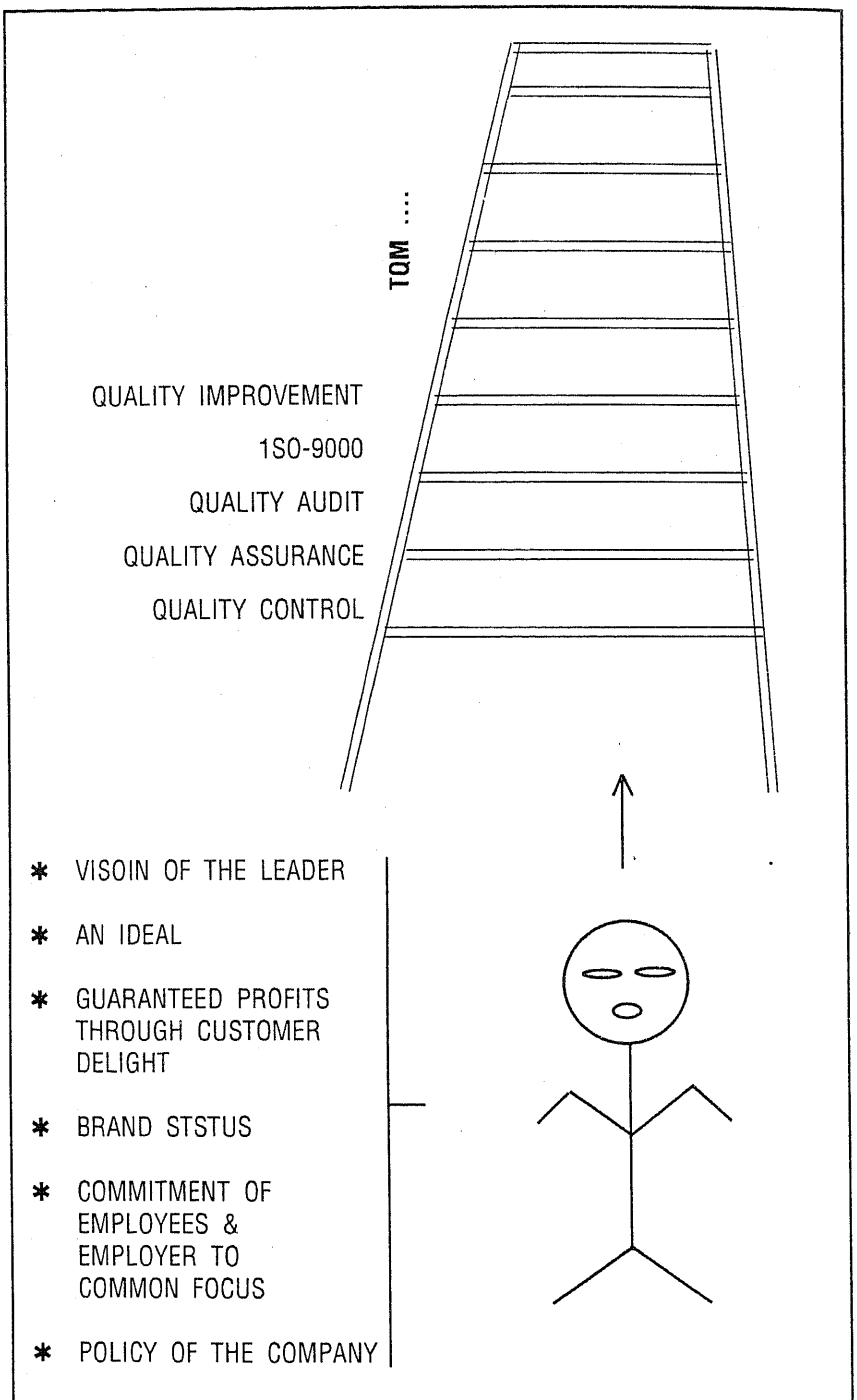

Fig. 1

and expertise. Stage 1 and 2 represent the study of trends in important parameters of product/ service quality and supplier/service quality, respectively. Stage 3 represents the need for synergism between suppliers and manufacturers, whereas stage 4 lays emphasis on this synergism among various processes. The next stage, stage 5, is reached when the company achieves quality in most of its ventures. Stages 6 and 7 focus on result monitoring. The former stage is reached when improvements are synchronised with results, and the latter, when these results are benchmarked with world class results. Further improvement in this direction for a minimum period of three years leads to stage 8. The penultimate stage is reached when quality levels are considered best in their respective categories of operation. We say that a company is in the threshold of achieving CQM if it sustains this level of world class quality in all of its areas for a minimum period of three years. Note the emphasis laid on the interrelationship between the manufacturer/utility, the product, process and the suppliers, central to all of these being the customer.

The Genesis of CQM

It is obvious that in order to achieve CQM it is necessary that strict control is laid on these individual stages. However, individual stages are but the smaller constituents of a larger system. In a systems approach such as this, the performances of the smaller components become very important, in rating the overall performance of the larger system. In essence, each of the smaller systems, be it a small product/ simple service/etc., needs to imbibe the quality focus as efficiently as the larger system does. Independent and random assessment of any of these smaller constituents, should reflect the quality consciousness of the larger system/ company, much as each DNA (smaller constituent) of our body (larger system) carries the same fundamental information. This is schematically expressed in **Fig. 2**. Figure 2 shows that for continuous Quality improvement it is essential to intertwine Planning, Involvement, Doing (Performance), Measurement and Analysis. This relationship is shown as a DNA fragment in order to drive home the point that every simpler constituent / individual of a larger system should inherit each of these qualities on a continuous basis, in order to achieve CQM for the larger system, i.e., the Company as a whole. How to go about achieving these objectives in each of the stages? Nondestructive Testing holds the key.

NONDESTRUCTIVE TESTING & CQM

Each of these stages, in any product or service, can be strictly monitored using Nondestructive Testing (NDT). Two aspects assume importance here, regarding the use and role of NDT in achieving CQM. Firstly, the term Nondestructive Testing is used here, not merely as an assembly of well established conventional

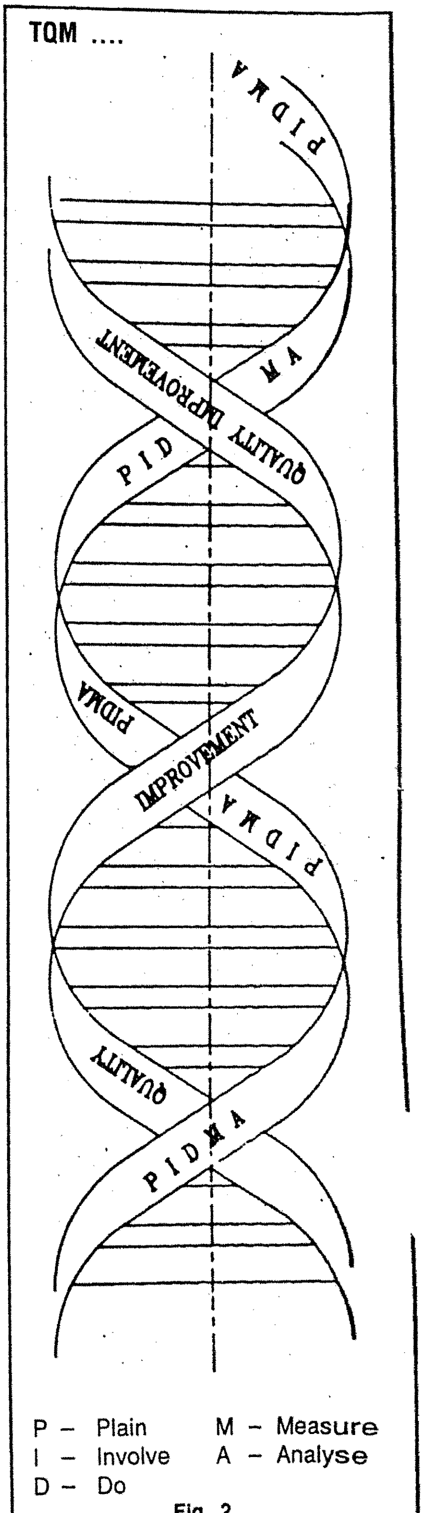

Fig. 2

NDT techniques, but as a complete embodiment of interdisciplinary areas, right from Physics on the one side to Computer Science on the other, working together to bring out a distinct synergistic advantage. Secondly, the role of NDT as envisaged in any CQM program is one that focusses on prevention rather than cure. Doing things the right way, even if it is done for the first time and repeating this every time, is the fundamental aspect of CQM. In other words, the concept of zero-defect (100% Quality Assurance) should be accorded prime importance. Testing and inspection of products and services as they evolve have assumed greater importance, rather than the NDT of finished products. In the final phases of the evolution of CQM, NDT of finished products may also become a thing of the past. Similarly, Acceptable Quality Level (AQL) is a concept that is totally opposed to CQM, and is often preached by companies that cannot get their act together to achieve CQM. An AQL is subjective and more often sets up a dual standard. AQL is also contradictory to the accepted norm of continuous improvement. CQM requires 100% reliability in the products, services and commitment of the people of the organisation which strives to obtain CQM.

NEW CONCEPTS THAT AID COMPREHENSIVE QUALITY MANAGEMENT OF WELDS

On-line monitoring of welds towards achieving cost effective reliability

The reliability and consistency of welds produced can be enhanced through the use of real time (in-time) monitoring. This approach enables assessment and control of the welding process. Presently, success of automatic/robotic welding systems have been confined to repetitive and large scale fabrication jobs. The present day automatic welding systems do not have the adaptive features of welding process control, unlike manual welding wherein the welder alters the welding parameters utilizing his experience and depending on his visual observations during welding. An approach to the adaptable and automatic welding systems lies in the development of on-line sensing techniques capable of giving precise information about the appearance of defects. On-line techniques are particularly useful and cost effective for high technology industries like nuclear, aerospace etc. where welds with stringent specification for defects acceptance are a must for higher reliability. Two such techniques for on-line sensing are thermography and acoustic emission (AE). Thermography and AE techniques give real time information regarding weld quality and defect formation thus offering on-line possibility of rectification of the welding procedure resulting in reduced scrap and repairs. Thus the need for post weld NDT techniques for examination is reduced. This helps in timely completion and also reduces financial and man-hour requirements. The advantage is particularly important for thicker weldments as rectification and repair costs are significantly reduced by on-line monitoring approach. On-line monitoring can be utilized for welders' qualification/training for specialized jobs as the welder gets additional information about his capabilities and inadequacies. In the case of resistance spot welding, weld quality can be immediately known without the necessity for destructive testing of samples.

Intelligent Welding Processes

A real time ultrasonic system has been developed for on-line monitoring and control of multipass process. Experimental results show that it is possible to detect and locate liquid/solid weld pool interface. The measurements enable understanding the influence of high temperature gradients near the molten zones on the ultrasonic wave propagation. Artificial defects are introduced in the already completed weld pass. Detection and location of these defects during welding of subsequent pass by accounting for the beam propagation behavior in the complex weld pool one is in progress. The ultimate aim is detection of formation of defects during welding process itself so that corrective action can be taken immediately by feed-back control intelligent algorithms.

Use of AI towards enhanced reliability of weldments

One of the emerging possibilities to effectively utilise the weld and welding knowledge is to explore the concepts of artificial intelligence (AI) wherever applicable. Successful implementations of AI concepts, in the form of verified and validated knowledge based systems (KBS) and knowledge based inference mechanisms have been realised. A major research and development effort is being directed to realise more efficient systems of this kind. Utilising the results of AI for problem solving, KBS have become a commercially successful demonstration of the power of AI techniques. A KBS is ideally suited (a) when problems cannot be well defined analytically, and the number of alternate solutions is large, (b) the domain of knowledge is vast and (c) relevant knowledge needs to be identified rapidly, as it is to be used selectively. Proper organisation and effective use of the available knowledge, in the form of an integrated KBS, will help taking quick and reliable decisions regarding ultrasonic and radiographic procedures and techniques (conventional/signal/image analysis) to be adopted for efficient nondestructive evaluation of welds. One such integrated knowledge based system, has been developed in the author's laboratory, to be used as an advisor for ultrasonic testing of austenitic stainless steel welds.

CONCLUSION

Comprehensive quality management of welded components is achieved through adequate appreciation of materials and their weldabilities, properties of welding consumables, characteristics of welding processes, the conditions that would be present during performance of the component, possible failure mechanisms and application of advanced yet appropriate NDT methodologies and procedures.

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