Ministry of Education and Science of the Russian Federation
Federal Independent Educational Institution
"NATIONAL RESEARCH TOMSK POLYTECHNIC UNIVERSITY"

School School of nuclear science and engineering

Direction of training 14.04.02 Nuclear Physics and Technologies

Division Division of Nuclear-Fuel cycle

MASTER'S THESIS

Topic of the work
Application of phased arrays in ultrasonic nondestructive testing

UDC 620.179.162

Student

Group	Full name	Signature	Date
0АМ6И	Parimala Rangan Fidel Castro		

Scientific Supervisor

Position	Full name	Academic degree, academic rank	Signature	Date
Engineer, TOLMI, School of Non-Destructive Testing & Security	Dolmatov D.O.			

ADVISORS:

Section "Financial Management, Resource Efficiency and Resource Saving"

Position	Full name	Academic degree, academic rank	Signature	Date
Associate Professor, School of Engineering Entrepreneurship	Rakhimov T.R.	PhD, Associate Professor		

Section "Social Responsibility"

Position	Full name	Academic degree, academic rank	Signature	Date
Senior lecturer	Verigin D.A.	PhD		

ADMIT TO DEFENSE:

Head of the Division	Full name	Academic degree, academic rank	Signature	Date
Division of Nuclear-Fuel Cycle	Goryunov A.G. .	Doctor of Technical Sciences, Professor		

Tomsk – 2018

Expected learning outcomes

Result code	The result of the training (the graduate should be ready)	Requirements of the FSES HE, criteria and / or stakeholders
	professional competencies	
LO1	To apply deep mathematical, natural scientific, socio-economic and professional knowledge for theoretical and experimental research in the field of the use of nuclear science and technology	FSES HE Requirements (PC-1,2, 3, 6, UC-1,3), Criterion 5 RAEE (p 1.1)
LO2	Ability to define, formulate and solve interdisciplinary engineering tasks in the nuclear field using professional knowledge and modern research methods	FSES HE Requirements (PC-2,6,9,10,14 UC-2,3,4, BPC1,2), Criterion 5 RAEE (p 1.2)
LO3	Be able to plan and conduct analytical, simulation and experimental studies in complex and uncertain conditions using modern technologies, and also critically evaluate the results	FSES HE Requirements (PC-4,5,6,9,22 UC-1,2,5,6), Criterion 5 RAEE (p 1.3)
LO4	To use the basic and special approaches, skills and methods for identification, analysis and solution of technical problems in nuclear science and technology	FSES HE Requirements (PC-7,10,11,12,13 UC-1-3,BPC1,3), Criterion 5 RAEE (p 1.4)
LO5	Readiness for the operation of modern physical equipment and instruments, to the mastery of technological processes during the preparation of the production of new materials, instruments, installations and systems	FSES HE Requirements (PC-8,11,14,15, BPC-1), Criterion 5 RAEE (p 1.3)
LO6	The ability to develop multivariate schemes for achieving the set production goals, with the effective use of available technical means	FSES HE Requirements (PC-12,13,14,16, BPC-2), Criterion 5 RAEE (p 1.3)
	cultural competencies	
LO7	The ability to use the creative approach to develop new ideas and methods for designing nuclear facilities, as well as modernize and improve the applied technologies of nuclear production	FSES HE Requirements (PC-2,6,9,10,14, UC-1,2,3), Criterion 5 RAEE (p 1.2,2.4,2.5)
	basic professional competencies	
LO8	Independently to study and continuously to raise qualification during all period of professional work.	FSES HE Requirements (PC-16,17,21, UC-5,6, BPC-1), Criterion 5 RAEE (p 2.6) coordi-nated with the requirements of the international standard

		EURACE & FEANI
LO9	Actively own a foreign language at a level that allows you to work in a foreign language environment, develop documentation, present results of professional activity.	FSES HE Requirements (BPC-3, UC-2,4), Criterion 5 RAEE (p 2.2)
LO10	To demonstrate independent thinking, to function effectively in command-oriented tasks and to have a high level of productivity in the professional (sectoral), ethical and social environments, and also to lead the team, form assignments, assign responsibilities and bear responsibility for the results of work	FSES HE Requirements (PC-18,20,21,22,23 UC-1,4, BPC-2), Criterion 5 RAEE (p 1.6,2.3) coordinated with the requirements of the international standard EUR-ACE & FEANI

The form of the assignment for the Master's Thesis completion

Ministry of Education and Science of the Russian Federation
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School School of nuclear science and engineering
Direction of training 14.04.02 Nuclear Physics and Technologies
Division Division of nuclear fuel cycle

APPROVED BY:
Head of the Division
______ ________ ______________
(Signature) (Date) (Full name)

ASSIGNMENT
for the Master's Thesis completion

In the form:

Master's Thesis

For a student:

Group	Full name
0AM6И	Parimala Rangan Fidel Castro

Topic of the work:

Application of phased arrays in ultrasonic nondestructive testing	
Approved by the order of the Head (date, number)	

Deadline for completion of the Master's Thesis:	

TERMS OF REFERENCE:

Initial data for work *(the name of the object of research or design; performance or load; mode of operation (continuous, periodic, cyclic, etc.); type of raw material or material of the product; requirements for the product, product or process; special requirements to the features of the operation of the object or product in terms of operational safety, environmental impact, energy costs; economic analysis, etc.).*	– the CIVA software; – phased array Olympus 5L16-A1; – electronic unit OPTUS; – testing specimens.
List of the issues to be investigated, designed and developed *(analytical review of literary sources in order to elucidate the achievements of world science and technology in the field under consideration, the formulation of the problem of research, design, construction, the content of the procedure of the research, design, construction, discussion of the performed work results, the name of additional sections to be developed; work conclusion).*	– analytical review of literature sources for the determining the state of the art of ultrasonic nondestructive testing; – determination of the most promising techniques for ultrasonic imaging with phased arrays; – the analytical comparison of techniques of ultrasonic imaging with phased arrays by the application of CIVA software;

	– experimental verification of results obtained via the computer simulations.
List of graphic material *(with an exact indication of mandatory drawings)*	

Advisors on the sections of the Master's Thesis
(with indication of sections)

Section	Консультант
Financial Management, Resource Efficiency and Resource Saving	Rakhimov T.R.
Social Responsibility	Verigin D.A.

Date of issuance of the assignment for Master's Thesis completion according to a line schedule	

The task was issued by the Head:

Position	Full name	Academic degree, academic status	Signature	Date
Engineer, TOLMI School of Non-Destructive Testing & Security	Dolmatov D.O.			

The assignment was accepted for execution by the student:

Croup	Full name	Signature	Date
0АМ6И	Parimala Rangan Fidel Castro		

TASK FOR MASTER'S THESIS SECTION
"FINANCIAL MANAGEMENT, RESOURCE EFFICIENCY AND RESOURCE CONSERVATION"

Student:

Group	Name
0АМ6И	Parimala Rangan Fidel Castro

Institute	Nuclear Science and Engineering	**Department of**	Nuclear Power Plant
Education Level	Masters	**Direction / specialty**	Nuclear Power Installations and Operation

References for "Financial management, resource efficiency and resource conservation":	
1. The cost of research: Logistics, energy, financial, information and human	*According to manual provided*
2. Norms and standards resource consumption	*According to manual provided*
3. used the tax system, tax rates, deductions, discounting and credit	*According to manual provided*
The list of questions for study, design and development:	
1. Evaluation of commercial and innovative potential STI	**Implement** at least 1 option from the list (1-6) below: 1. Potential consumers of research results 2. Analysis of competitive technical solutions from the perspective of resource efficiency and resource savings 3. Technology QUAD 4. FAST-analysis 5. Diagram Ishikawa 6. SWOT-analysis **Perform** • Evaluation of the project readiness for commercialization • Methods for the commercialization of scientific and technological research
2. Development of the charter of scientific and technical project	• Objectives and outcomes of the project. • The organizational structure of the project. • Identification of possible alternatives
3. Project management planning: the structure and schedule of the budget, risk and procurement organization	• The structure of the work within the framework of scientific research • Determination of the complexity of work • Scheduling scientific research • The budget of the scientific and technical research (STR)
4. Defining resource, financial, economic efficiency	• Integral financial efficiency indicator • Integral resource-efficiency indicator • Integral total efficiency indicator • Comparative project efficiency indicator
List of graphic material	

1. *Segmentation of the market* 2. *Estimation of competitiveness of technical solutions* 3. *FAST-Chart* 4. *SWOT Matrix* 5. *Schedule and budget of the project* 6. *Assessment resource, financial and economic efficiency of the project*

Date of issue of assignment	

Assignment given by consultant:

Position	Name	degree	Signature	Date
Associate Professor	**Timur R. Rakhimov**	**PhD Economics**		

Assignment received by student for implementation:

Group	Name	Signature	Date
0АМ6И	Parimala Rangan Fidel Castro		

Ministry of Education and Science of the Russian Federation
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"NATIONAL RESEARCH TOMSK POLYTECHNIC UNIVERSITY"

School School of nuclear science and engineering
Direction of training (Specialty) 14.04.02 Nuclear Physics and Technologies
Level of education Master's degree
Division Division of Nuclear-Fuel cycle
Period of completion spring semester of 2017/2018 educational year

Form of presenting the work:

Master's Thesis

SCHEDULED COURSE ASSESSMENT CALENDAR
for the Master's Thesis completion

Deadline for completion of the Master's Thesis:	22.05.2018

Assessment date	Title of section (module) / type of work (research)	Maximum score of the section (module)
14.03.2018	*The obtaining of the assignment*	…
04.03.2018	*Analytical review of the literature sources in order to determine the current state of the art of ultrasonic nondestructive testing*	…
25.03.2018	*Analytical comparison of ultrasound imaging techniques with phased arrays using the CIVA software package;*	
06. 04.2018	*Experimental verification of results obtained via the simulation*	
06.05.2018	*The analysis of obtained results*	
22.05.2018	*The finish of the work*	

Made by lecturer:

Position	Full name	Academic degree, academic status	Signature	Date
Engineer, TOLMI School of Non-Destructive Testing & Security	Dolmatov D.O.			

AGREED::

Head of the Division	Full name	Academic degree, academic status	Signature	Date
Division of Nuclear-Fuel Cycle	Goryunov A.G.	Doctor of Technical Sciences, Professor		

Abstract

Master’s Thesis 112p., 38 fig., 18 tabl.and 45 references.

Key words: Ultrasonic testing; Ultrasonic imaging, phased arrays, Total Focusing Method, Plane Wave Imaging, Electronic Focusing, computer simulations, CIVA software.

The object of the research is ultrasonic nondestructive testing.

The purpose of the work is to make analytical comparison of the techniques for ultrasonic with phased arrays.

In the course of research the most promising techniques for ultrasonic imaging with phased arrays was determined according to analytical study of literature sources. The comparison of these techniques was conducted by the application of computer simulations which was made in CIVA software. Results obtained through the simulations were verified via the real experiment.

As a result of research the technique which provides the most quality imageries of internal structure of testing objects was defined.

Basic structural, technological and technical-operational characteristics: Applies only to laboratory installation.

Degree of implementation: Implementation of obtained results for the developing of advanced ultrasonic imaging systems

Application area: development of advanced ultrasonic imaging systems.

Economic efficiency/significance of research outcomes is the application of results for the reducing the cost and increasing the reliability of ultrasonic testing.

Future prospects: the additional example of the inspection further explores the real world uses of on scale in NDE applications.

Table of contents

Introduction

The utilization of ultrasonic phased array frameworks for non-destructive assessment (NDE) has expanded drastically lately. Such frameworks have been utilized for a long time in the field of Non-destructive testing. Non-destructive testing strategies assume an imperative part in surveying the honesty of solid structures [1]. NDT techniques help distinguish potential shortcomings or basic insufficiencies early so Nuclear industries can address them before unnecessary downtime or loss of energy age capabilities happen. Such strategies guarantee the security of the nuclear power plant and fill in as verification to government organizations that the organization is proactive in their checking and administrative consistence programs. While imperative for testing of solid structures, ultrasonic strategies are similarly as basic to testing mechanical frameworks and segments, for example, boilers, heat exchangers and piping frameworks. Ultrasonic testing can likewise be utilized to check the uprightness of welds and different kinds of parts, for example, valves and nozzles. These methods can be connected to an assortment of atomic plant reviews, including metallic and non-metallic materials. Such testing can be completed amid new plant development, routine support or when a specific part is arriving at the finish of its lifecycle. Regardless of the circumstance, testing and investigation are fundamental to plant operation. Ultrasonic testing can survey the present state of a segment or framework and enable work force to assess whether it is fit for benefit and the rest of the administration life. Atomic plants must supply continuous energy to the electrical network. In any case, safety is of most extreme significance, both that of the overall population and plant representatives. NDT systems are demonstrated to satisfy the two targets. Such procedures additionally meet the objectives of improving unwavering quality of plant assets. New ultrasonic techniques are being created and utilized as a part of an assortment of uses to accomplish more precise outcomes to help achieve more accurate results to aids and safe in reliable operation. Different

NDT methods and techniques have been developed for monitoring degradation in nuclear industry which includes ultrasonic testing etc. Ultrasonic testing plays a vital role in carrying out testing in very complex structures, for example the Nuclear power sector on BWR and PWR. The development of advanced inspection technologies for nuclear power plant equipment such as phased array ultrasonic testing for inspecting inside the reactor (submersible ROVs), and guided-wave wall-thinning inspection of piping. The benefit of utilizing ultrasonic phased array in NDE over conventional single element transducers is the capacity to play out different investigations without the requirement for reconfiguration and furthermore the potential for enhanced affectability and scope. Phased array using Plane wave imaging and Electronic focusing are frequently used to expand the range and precision of assessment [2]. Flexible arrays and high temperature arrays are being produced to permit testing of components with complex geometries, and brutal situations particularly for inside the aviation and nuclear industries[3]. What's more air coupled exhibits are demonstrating noteworthy guarantee for NDE. In any case, in numerous zones of modern NDE the objective is static and it is sensible to complete information examination. In the case of phased array ultrasonic techniques which are used in nuclear industry the technique of ultrasonic testing is used for pipelines of main circulation circuit of nuclear power plant with VVER-1000 by using phased array. The phased array testing offers significant advantages for ultrasonic phased array of nuclear components due to its extended informational content provided by various capability [4]. Thus the combination of various scanning techniques increases the flaw detectability. Advances in computer technologies that it is generally brisk and simple to process a lot of information on a standard computer. The benefits of this approach are expanded affectability to little deformities and more noteworthy review scope. The point is first to characterize the post preparing calculations utilized for different technique by phased array. Analytical study and comparison of various techniques of ultrasonic non-destructive testing has been discussed.

1 Development and state of the art of ultrasonic non-destructive testing

1.1 Physical principles of ultrasonic non-destructive testing

Ultrasonic waves are acoustic waves whose frequency is more than 20 kHz. They travel with the speed of sound. Their wavelength is smaller than 1.66 cm. These waves possess a number of properties of sound waves and exhibit some new phenomena. They use high frequency sound energy to conduct examinations and make measurements. Ultrasonic inspection are utilized for flaw detection/evaluation, dimensional measurements, material characterization, and more. To illustrate the general inspection principle, a typical pulse/echo inspection configuration as illustrated below will be used. A regular ultrasonic testing assessment framework comprises of a few practical units, for example, the pulser/receiver, transducer, and display gadgets. Transducer creates high frequency ultrasonic energy. The sound energy is projected and engenders through the materials as waves. At the point when there is a discontinuity, such as crack in the wave path, some portion of the energy will be reflected over from the flaw surface. Figure1.1 shows the reflected wave signal is changed into an electrical signal by the transducer and is shown on a screen.

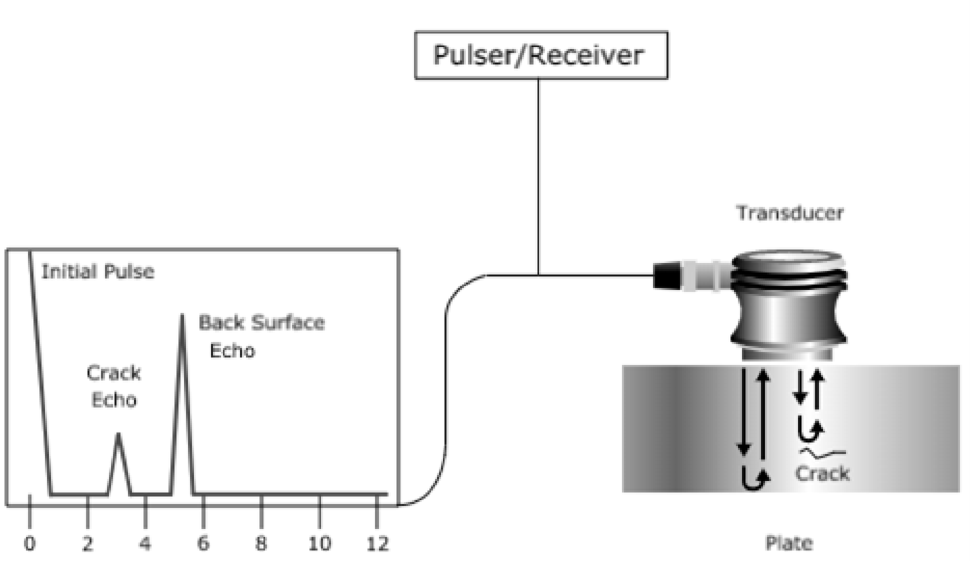


Figure 1.1 – Typical pulse/echo inspection

In the applet beneath, the reflected signal is shown versus the time from signal generation to when an echo was received. Signal travel time can be specifically identified with the separation that the signal travelled. From the signal, data about the reflector area, size, orientation and different features can now and again be picked. Ultrasonic testing is regularly performed on steel and different metals and alloys [5]. however it can likewise be utilized on concrete, wood and composites, yet with less resolution. It is utilized as a part of numerous enterprises including steel and aluminium development, metallurgy, fabricating, aviation, car and other transportation divisions. Ultrasonic waves can engender through a medium as stress or strain waves relying on the versatile properties of medium.

In view of particle displacement of the medium, ultrasonic waves are arranged into four sorts or modes:

– Longitudinal or Compressional or Pressure ultrasonic waves;

– Transverse or Shear ultrasonic waves;

– Surface or Rayleigh Waves;

– Lamb or Flexural or Plate Waves.

In the longitudinal waves particles of medium vibrate forward and backward parallel to the direction of propagation of waves. These waves spread through the medium as a progression of alternate compression and rarefaction. These waves are most broadly utilized as a part of the ultrasonic review of materials. This mode is shown when medium of propagation has no limits i.e. it has vast span. Because of propagation of these wave, both pressure and density of medium change intermittently. In the transverse wave particles of the medium vibrate opposite to the course of waves propagation. For this situation the medium experiences shear deformation intermittently. These waves can propagate through this pole. The surface waves travel along the level or bended surface of thick solids without affecting the bulk part of medium beneath the surface. The profundity to which these waves proliferate underneath the surface with impressive force is around equivalent to wavelength of the wave. These waves are utilized to recognize cracks or flaws on or close to the surface of test objects. Amid the engendering of surface waves, the particles of medium portray elliptical objects.

The advantages of ultrasonic nondestructive testing are the following:

– It is sensitive to both surface and subsurface discontinuities.

– The profundity of penetration for flaw detection or identification or estimation is better than other NDT strategies.

– Only single-sided access is required when the pulse echo strategy is utilized.

– It is exceedingly precise in deciding reflector position and evaluating size and shape.

– Minimal part preparation is required.

– Electronic hardware gives immediate outcomes.

– Detailed images can be produced with automated system.

– It has different utilizations, for example, thickness estimation, not with standing flaw detection.

Ultrasonic investigation likewise has its constraints, which include:

– Surface must be available to transmit ultrasound.

– Skill and training is more extensive than with some different techniques.

– It regularly requires a coupling medium to advance the exchange of sound energy into the test specimen.

– Materials that are rough, irregular in shape, little, astoundingly thin or not homogeneous are hard to assess.

– Cast iron and other coarse grained materials are hard to review because of low sound transmission and high signal noise.

– Linear defects oriented parallel to the sound beam may go undetected.

– Reference principles are required for both equipment calibration and characterization of flaws.

To successfully perform an examination utilizing ultrasonic, significantly more about the technique should be known. At the point when ultrasonic wave goes through an interface between two materials at an oblique angle, and the materials have distinctive list of refraction, both reflected and refracted waves are delivered [6]. Refraction happens at an interface because of the distinctive velocity of the acoustic waves within the two materials. The velocity of sound in every material is controlled by the material properties that material.

1.2 Snell's law

Snell's Law describes the relationship between the angles and the velocities of the waves. Snell's law equates the ratio of material velocities V_1 and V_2 to the ratio of the sine's of incident (Q_1) and refracted (Q_2) angles, as shown in the following equation:

$$\frac{\sin\emptyset_1}{v_{L1}} = \frac{\sin\emptyset_2}{v_{L2}} \qquad (1.1)$$

where: V_{L1} and V_{L2} – are the ratio of material velocities;

$\sin\emptyset_1$ *and* $\sin\emptyset_2$ – are the ratio of the sine's incident and sine's refracted angles.

Note that in the Figure1.2, there is a reflected longitudinal wave ($V_{L1'}$) shown. This wave is reflected at the same angle as the incident wave because the two waves are traveling in the same material, and hence have the same velocities. This reflected wave is unimportant in our explanation of Snell's Law, but it should be remembered that some of the wave energy is reflected at the interface. When a longitudinal wave moves from a slower to a faster material, there is an incident angle that makes the angle of refraction for the wave 90^o. This is known as the first critical angle. The first critical angle can be found from Snell's law by putting in an angle of 90° for the angle of the refracted ray. At the critical angle of incidence, much of the acoustic energy is in the form of an inhomogeneous compression wave, which travels along the interface and decays exponentially with depth from the interface. This wave is sometimes referred to as a "creep wave." Because of their inhomogeneous nature and the fact that they decay rapidly, creep waves are not used as extensively as Rayleigh surface waves in NDT.

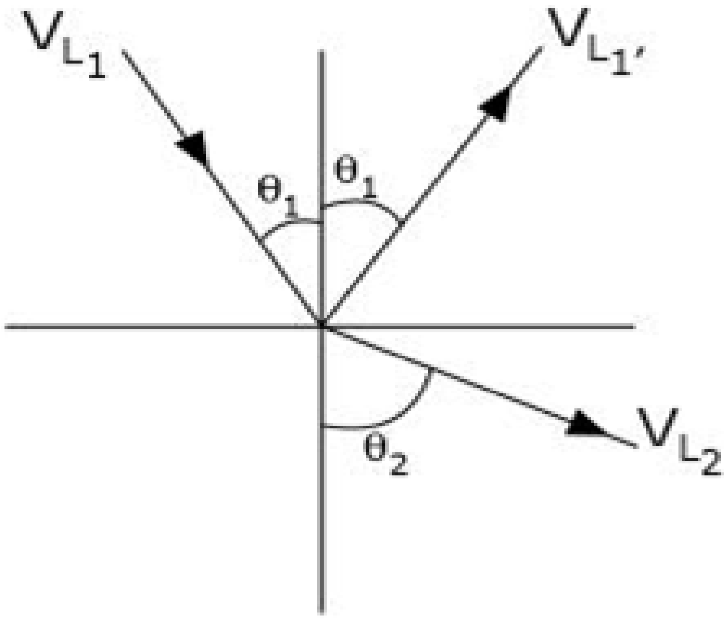


Figure 1.2 – Snell’s law presentation

However, creep waves are sometimes more useful than Rayleigh waves because they suffer less from surface irregularities and coarse material microstructure due to their longer wavelengths. Past the first critical angle, just the shear wave propagates into the material. Therefore, most angle beam transducers utilize a shear wave so the signal isn't complicated by having two waves present. By and large there is likewise an incident angle that influences the angle of refraction for the shear to wave 90 degrees. This is known as the second critical angle and now, all the wave energy is reflected or refracted into a surface after shear wave or shear creep wave. The sound that radiates from a piezoelectric transducer does not begin from a point, but rather starts from a large portion of the surface of the piezoelectric component.

1.3 Near field and far field of the ultrasonic transducer

Transducer as shown in Figure1.3 the sound field from a common piezoelectric transducer is demonstrated as follows. The intensity of the sound is shown by shading, with lighter colour demonstrating higher intensity. Since the ultrasound starts from various focuses along the transducer face, the ultrasound intensity along the beam is influenced by constructive and destructive wave obstruction. These are now and then additionally alluded to as diffraction effects. This wave interference prompts extensive fluctuation in the sound intensity near to the source and is known as the near field. Due to acoustic variation inside a near field, it can be hard to precisely assess flaws in materials when they are situated inside this region. The pressure waves combine to form a moderately uniform front at the end of the near field. The zone past the near field where the ultrasonic beam is more uniform is known as the far field. In the far field, the beam spreads out in a patter beginning from the focal point of the transducer. The progress between the near field and the far field happens at a separation, N, and is once in a while alluded to as the "natural focus" of a flat (or unfocused) transducer as shown in Figure1.4. The near/far field distance, N is huge because of amplitude variation that portray the near field change to an easily declining amplitude at this point.

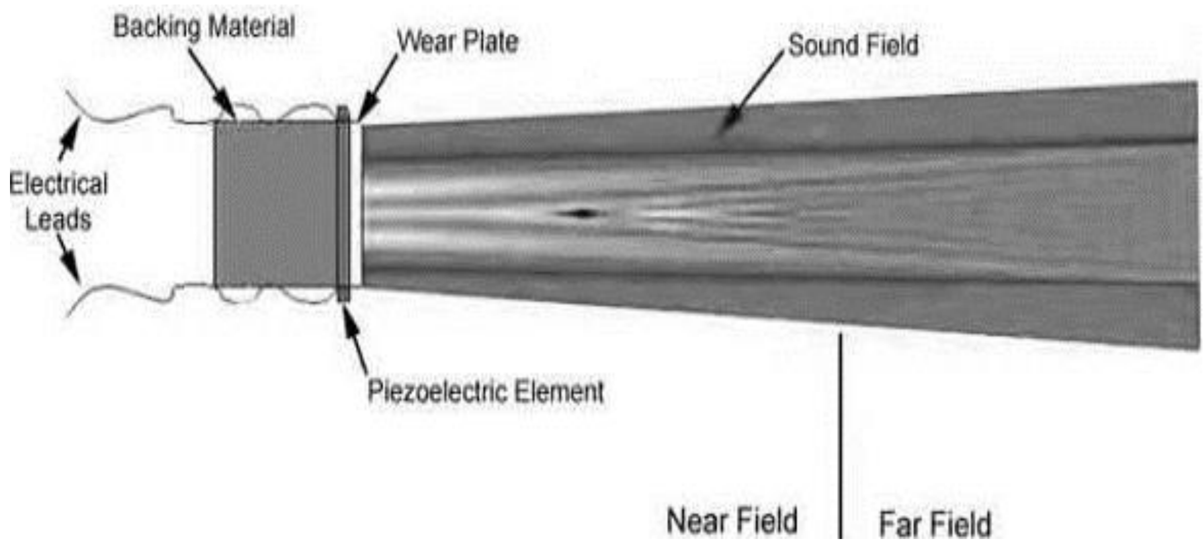


Figure 1.3 – Sound field from a typical piezoelectric transducer

The region just past the near field is the place the sound wave is all around behaved and at its greatest strength. Therefore, optimal detection results will be acquired when flaws occur in this area.

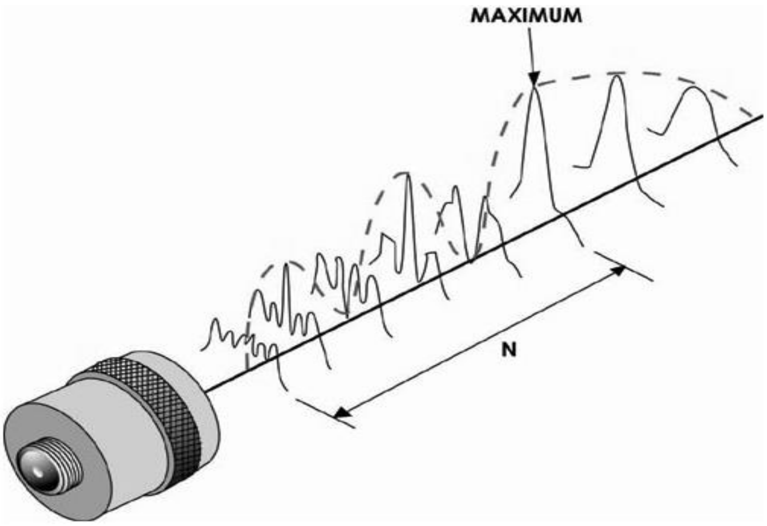


Figure 1.4 – Near and far field distance

1.4 Types of ultrasonic transducers

Ultrasonic waves are generated by the following ways:

– Laser Ultrasonic Generator;

– Magnetostriction Generator;

– Piezoelectric Generator.

In Laser-ultrasonic Generator method, generation of ultrasound begins from the absorption of light at the surface of the material, which makes a transient heat source, which thusly delivers the thermo-elastic stress at the origin of ultrasound. At higher laser power density thickness a thin surface layer is vaporized which, by the recoil effect delivers the typical stress at the origin of ultrasound. The qualities of ultrasonic sources delivered by lasers have been the object of intensive. Concerning the recognition aspect, the different methods have been utilized and the most suitable for industrial examination seem, by all accounts, to be founded on velocity or time-delay interferometry. The rule of these strategies is to make the wave scattered by the surface to interfere with itself after a delay. By practise, it is conceivable to fabricate an interferometer in which the delayed wave front coordinates adequately well the incoming wave front to give a light assembling efficiency sufficiently huge for valuable application. Two-wave interferometers were discovered superbly reasonable for detection at high frequencies (over 100MHz) various multiply wave interferometers have more appropriate in the low MHz range (1 - 20MHz), by and large utilized for inspecting grained or heterogenous materials.

Electromagnetic acoustic transducer (EMAT) is a transducer for non-contact sound age and gathering utilizing electromagnetic instruments. EMAT is an ultrasonic non-destructive testing (NDT) strategy which does not require contact or couplant, in light of the fact that the sound is specifically created inside the material contiguous the transducer [7]. There are two components to create waves through magnetic field interaction. One is Lorentz force when the material is conductive. The other is magnetostriction when the material is ferromagnetic.

Lorentz force: The AC current in the electric coil produces eddy current on the surface of the material. As per hypothesis of electromagnetic induction, the conveyance of the eddy current is just at a thin layer of the material, called skin depth. This profundity lessens with the expansion of AC frequency, the material conductivity, and penetrability. Normally for 1 MHz AC excitation, the skin depth is just a small amount of a millimeter for essential metals like steel, copper and aluminum. The eddy current in the magnetic field encounters Lorentz force. In an infinitesimal view, the Lorentz force is connected on the electrons in the eddy current. In a naturally visible view, the Lorentz force is applied on the surface region of the material because of collaboration amongst electrons and particles. The dissemination of Lorentz force is controlled by the design of magnet and of the electric coil, the properties of the test material, relative position between the transducer and the test part, and the excitation signal for the transducer.

Magnetostriction: A ferromagnetic material will have a dimensional change when an outer magnetic field is connected. This impact is called magnetostriction. The motion field of a magnet grows or crumples relies upon the plan of ferromagnetic material having prompting voltage in a loop and the measure of progress is influenced by the magnitude and course of the field. The AC current in the electric coil instigates an AC magnetic field and in this manner produces magnetostriction at ultrasonic frequency in the material. The unsettling influences caused by magnetostriction at that point proliferate in the material as an ultrasound wave. In polycrystalline material, the magnetostriction reaction is exceptionally convoluted. It is influenced by direction of the bias field, heading of the field from AC electric coil, the quality of bias field, and the amplitude of the AC current. At times, maybe a couple crest reaction might be seen with the expansion of bias field [8]. Now and again, the reaction can be enhanced essentially with the alter of relative direction between bias magnetic field and AC magnetic field. Quantitatively, the magnetostriction might be portrayed in a comparable numerical format as piezoelectric constants. Empirically, a ton of experience is expected to completely comprehend the magnetostriction marvel.

EMAT probes have the accompanying advantages, Contrasted with piezoelectric transducers:

– No couplant is required. In view of the transduction system of EMAT, couplant isn't required. This makes EMAT perfect for assessments at temperatures beneath the point of freezing or more than the evaporation purpose of fluid couplants. It additionally makes it advantageous for circumstances where couplant dealing with would be unreasonable.

– EMAT is a non-contact strategy. Despite the fact that proximity is favored, a physical contact between the transducer and the specimen under test isn't required.

– Dry Inspection. Since no couplant is required, the EMAT assessment can be performed in a dry domain.

– Less touchy to surface condition. With contact-based piezoelectric transducers, the test surface must be machined easily to guarantee coupling. Utilizing EMAT, the prerequisites to surface smoothness are less stringent; the main necessity is to evacuate loose scale and so forth.

– Simpler for sensor sending. Utilizing piezoelectric transducer, the wave propagation angle in the test part is influenced by Snell's law. Thus, a little variety in sensor deployment may cause a critical change in the refracted angle.

– Less demanding to create Shear horizontal type waves. Utilizing piezoelectric transducers, SH wave is hard to couple to the test part. EMAT gives a helpful methods for creating SH bulk wave and SH guided waves.

Disadvantages and drawbacks of the hindrances of EMAT contrasted with piezoelectric UT can be summarised as takes after:

– Low transduction effectiveness. EMAT transducers normally deliver raw signal of lower power than piezoelectric transducers. Therefore, more advanced signal handling strategies are expected to segregate signal from noise.

– Constrained to metallic or magnetic items. NDT of plastic and clay material isn't reasonable or if nothing else not helpful utilizing EMAT.

– Measure imperatives. Despite the fact that there are EMAT transducers as little as a penny, generally utilized transducers are expansive in estimate.

– Low profile EMAT issues are still under innovative work. Because of the size limitations, EMAT phased array is likewise hard to be produced using little components.

– Alert must be grasped when taking care of magnets around steel items.

Applications of EMAT has been utilized as a part of a wide scope of uses and can possibly be utilized as a part of numerous different applications. A brief and fragmented rundown is as per the following.

– Thickness estimation for different applications

– Imperfection detection in steel items

– Plate cover deformity investigation

– Different weld investigation for coil joint, tubes and pipes.

– Pipeline in-benefit inspection.

– Railroad and wheel review

– Austenitic weld review for power industry

The piezoelectric effect alludes to an adjustment in electric polarization that is delivered in specific materials when they are subjected to mechanical stress. This stress dependent change in polarization shows as a quantifiable potential contrast over the material. Referred to as the direct piezoelectric effect, this method is recognizable in numerous normally accessible crystalline materials, including quartz, Rochelle salt, and even human bone. Designed materials, for example, lithium niobate and lead zirconate titanate (PZT), display a more articulated piezoelectric effect. An essential component to note about this marvel is that the procedure is reversible. The inverse piezoelectric effect alludes to a deformation of these materials that outcomes from the use of an electric field [8]. The distortion could prompt either tensile or compressive strains and stress in the material relying on the direction of the electric field, the preferred direction of polarization in the material, and how the material is associated with other adjoining structures.

There are a few points of interest of piezoelectric transducer which are given underneath:

– The piezoelectric transducer is accessible fit as a fiddle.
– It has tough development.
– It is little in measure.
– It has great frequency reaction.
– It has irrelevant phase shift.

There are a few disservices disadvantages of piezoelectric transducer which are given underneath

– The piezoelectric transducer is utilized only for dynamic estimation.

1.5 Piezoelectric ultrasonic transducers

Ultrasonic transducers are made for an assortment of uses and can be exclusively created when essential. Careful consideration must be paid to choose the best transducer for the application. All variety of ultrasonic transducers can be divided as immersion and contact ultrasonic transducers.

Contact transducers are utilized for direct contact inspection, and are usually hand controlled. They have components secured in a rugged casing to withstand sliding contact with an assortment of materials. These transducers have an ergonomic design so they are easy to grip and move along a surface. They frequently have replaceable wear plates to stretch their valuable life. Coupling materials of water, oil, grease or commercial materials are utilized to expel the air gap between the transducer and the component being assessed. Figure1.5 demonstrates a model of contact transducer [9].

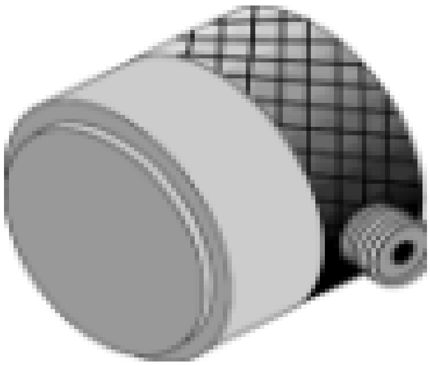


Figure 1.5 – Contact transducer

Immersion transducers dosen't contact the component. These transducers are intended to work in a fluid situation and all associations are watertight. immersion transducers more often have an impedance coordinating layer that gets more sound energy into the water and, thus, into the part being reviewed. Immersion transducers can be obtained with a planer, cylindrical focused or roundly focused lens. A focused transducer can enhance the sensitivity and axial determination by concentrating the sound energy to a smaller region. Figure1.6 demonstrates a model of immersion transducers.

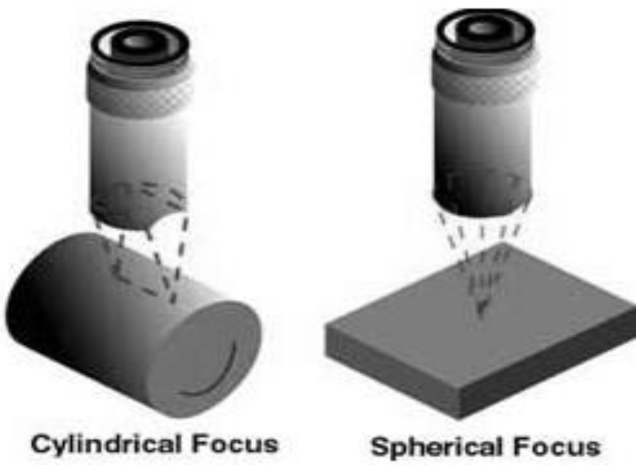


Figure 1.6 – Immersion transducers

Immersion transducers are normally utilized inside a water tank or as a component of a bubbler framework in scanning applications [9].

Specific contact ultrasonic transducers can be used for increasing the resolution of ultrasonic testing. Specific ultrasonic transducers include:

– delay line transducers;
– angle beam transducers;
– paint brush transducers;
– dual element transducers.

Delay line transducers furnish flexibility with an assortment of replaceable choices. Removable delay line, surface conforming membrane, and defensive wear cap alternatives can make a single transducer viable for an extensive variety of utilizations. As the name infers, the essential capacity of a delay line transducer is to introduce a time delay between the generation of the sound wave and the arrival of any reflected waves. This enables the transducer to finish its "sending" function before it begins its "listening" function so that close surface determination is improved. They are intended for use in applications, for example, high accuracy thickness, measuring of thin materials and delamination checks in composite materials [9]. They are additionally helpful in high-temperature estimation applications since the delay line gives some protection to the piezoelectric component from the heat as show in Figure1.7.

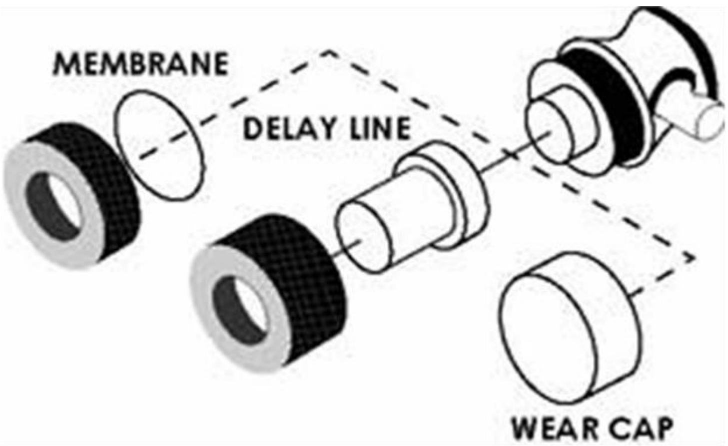


Figure 1.7 – Delay line transducers

Angle beam transducers and wedges are normally used to bring a refracted shear wave into the test material as appeared in Figure1.8 Transducers can be obtained in an assortment of fixed angles or in movable versions where the client decides the angles of occurrence and refraction. In the fixed angle versions, the angle of refraction that is set on the transducer is exact for a specific material, which is generally steel. The angled sound path enables the sound beam to be reflected from the back wall to enhance detectability of flaws in and around welded territories. They are likewise used to create surface waves for use in identifying defects on the surface of an element [26]. Normal incidence shear wave transducers are extraordinary because they permit the introduction of shear wave straightforwardly into a test piece without the utilization of an angle beam wedge. Cautious design has empowered assembling of transducers with negligible longitudinal wave contamination. The proportion of the longitudinal to shear wave component is for the most part underneath - 30dB.

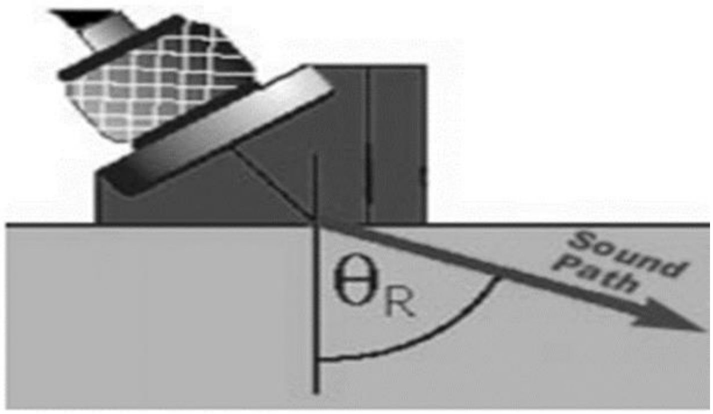


Figure 1.8 – Angle beam transducers

Paint brush transducer are utilized to examine wide zones. These long and narrowed transducers are comprised of a variety small crystals that are precisely coordinated to limit variations in execution and keep up uniform sensitivity over the whole zone of the transducer. Paint brush transducers make it conceivable to examine a bigger territory all the more quickly for discontinuities. Smaller and more sensitive transducers are regularly at that point required to additionally characterize the elements of discontinuity.

Ultrasonic transducer cannot only be single element but also multi element. Transducers extraordinarily adopted to air coupling have indicated great performances at frequencies upto 5MHz. Diverse labs and organizations have begun utilizing these transducers for standard NDT. All things considered almost without work have been made to broaden the Phased array. A phased array ultrasonic transducer is normally 2-3 cm long, comprising of 64-128 components. It is a smaller assembly than a sequential array and can be either liner or curvilinear. A sector field of view is delivered by all components terminating to make a single waveform. Small delays in element terminating take into account for electronic field steering and focusing without moving the ultrasound probe. All components will be fired numerous circumstances with various degrees of steering to make an image. Echoes are identified by all elements and entered into a algorithm to frame the image. Line density diminishes at the bottom of the image. The sensitivity of the image decreases at extremes of steering and lateral determination is best in the centre of the field of view because of a larger effective aperture.

Dual element transducers contain two autonomously operated components in a single housing. One of the elements transmits and alternate gets the ultrasonic signal. Dynamic components can be decided for their sending and receiving capabilities to give a transducer a cleaner signal, and transducers for extraordinary applications, for example, the assessment coarse grained material. Dual element transducers are particularly appropriate for making measurements in applications where reflectors are exceptionally close to the transducer since this outline disposes of the ring down effect that single component transducers encounter. When single elements transducers are working in beat pulse echo mode, the component can't start receiving reflected signals until the elements stop for its transmit function. Dual element transducers are extremely helpful when making thickness estimations of thin materials and while reviewing for close surface imperfections as appeared in

Figure1.9. The two components are angled towards each other to make a crossed-beam sound path in the test material [26].

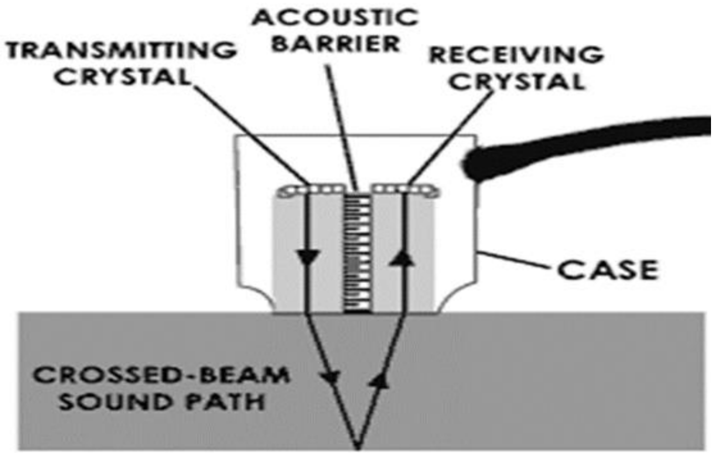


Figure 1.9 – Dual element transducer

Furthermore, all variety of piezoelectric ultrasonic transducers can be divided on single-element and multi-element transducers. Multi-element transducers include dual-element probes which were mentioned above and phased arrays. Phased array probes, commonly comprise of a transducer gathering with from 16 to upwards of 256 little individual components that can each be pulsed independently. The advantages of phased array innovation over ordinary UT originate from its capacity to utilize various components to steer, focus and scan beams with a single transducer assembly. Beams steering, ordinarily referred to sectorial scanning, can be utilized for mapping components at appropriate angles [9]. Sectorial scanning is additionally normally utilized for weld inspection. The capacity to test welds with numerous angles from a single probe extraordinarily builds the likelihood of detection of abnormalities.

The potential disadvantages of phased array system are somewhat higher cost and a necessity for administrator preparing, however these expenses are frequently offset by greater flexibility and a diminishment in the time required to perform a given inspection.

1.6 Standards in ultrasonic testing with phased array

In the field of non-destructive testing (NDT), several organizations are involved in the development and application of standards, including the American Society for Non-destructive Testing (ASNT); ASTM International, formerly known as the American Society for Testing and Materials (ASTM); and the International Organization for Standardization (ISO). It depends on industry and materials. You can find a collection of Standards giving a good overview. As PAUT is a subgroup of ultrasonic testing, you need all ultrasonic standards too. Same you may do for EN-Standards and ISO, but the differences are marginal. But there are a lot of industrial specific Standards, often set by Industry leading OEMs. So as in nuclear industry, where you have to stick to Standards as their fields of application are often not covered and the OEM is responsible to establish a common System for all suppliers and risk sharing Partners. Example for specific material as CFRP no other than the big companies have such a long industrial experience in that field, so that even Research Institutes are often Greenhorns in that field, they miss the in-service experience and the high volume production expereince.

Various ultrasonic phased array standards:

– ISO(International Organization for Standardization) 18563-1:2015

– ISO(International Organization for Standardization) 18563-2:2017

– ISO (International Organization for Standardization)18563-3:2015

– ISO (International Organization for Standardization)19675:2017

– ISO(International Organization for Standardization) 19285:2017

– BS EN(British Standard European Norm) 16392-2:2014

– BS EN(British Standard European Norm) 16018:2011

– ISO (International Organization for Standardization) 13588:2012.

– ISO (International Organization for Standardization)11666:2018

ISO (International Organization for Standardization) 18563-1:2015: Identifies the functional characteristics of a multichannel ultrasonic phased array instrument used for phased array probes and provides methods for their measurement and verification. It can partly be applicable to ultrasonic phased array instruments in automated systems. When the phased array instrument is a part of an automated system, the acceptance criteria can be modified by agreement between the parties involved. It gives the extent of the verification and defines acceptance criteria within a frequency range of 0.5 MHz to 10MHz. The evaluation of these characteristics permits a well-defined description of the ultrasonic phased array instrument and comparability of instruments [10]. This piece of ISO 18563 distinguishes the practical attributes of a multichannel ultrasonic phased array instrument utilized for phased array probes and gives strategies to their estimation and confirmation. This piece of ISO 18563 can somewhat be relevant to ultrasonic phased array instruments in automated systems, yet at that point, different tests may be expected to guarantee palatable execution. At the point when the phased array instrument is a part of a computerized framework, the acknowledgment criteria can be changed by understanding between the parties involved. This part of ISO 18563 gives the degree of the check and characterizes acknowledgment criteria inside a frequency range of 0.5MHz to 10MHz. The assessment of these qualities allows an all around characterized portrayal of the ultrasonic phased array instrument and likeness of instruments.

ISO (International Organization for Standardization) 18563-2:2017 specifies the characterization tests performed at the end of the fabrication of a phased array probe. It defines both methodology and acceptance criteria. It is applicable to the following phased array probes used for ultrasonic non-destructive testing in contact technique (with or without a wedge) or in immersion technique, with centre frequencies in the range 0.5MHz to 10MHz. Non-matrix array probes which are linear, encircling, partial annular sectorial [11]. 2D-matrix array probes, it does not give methods and acceptance criteria to characterize the performance of an ultrasonic phased array instrument or the performance of a combined system. Record indicating consistence with ISO 18563-2 giving the deliberate estimations of the required parameters of one particular phased array probe, including test gear and conditions This piece of ISO 18563 tends to ultrasonic test frameworks executing linear phased array probes, in contact (with or without wedge) or in immersion, with centre frequencies in the scope of 0.5MHz – 10MHz..

ISO (International Organization for Standardization) 18563-3:2015 addresses ultrasonic test systems implementing linear phased array probes, in contact (with or without wedge) or in immersion, with centre frequencies in the range of 0.5MHz – 10MHz. It provides methods and acceptance criteria for verifying the performance of combined equipment (i.e. instrument, probe and cables connected). The methods described are suitable for users working under on-site or shop floor conditions [12]. Its purpose is for the verification of the correct operation of the system prior to testing, and also the characterization of sound beams or verification of the absence of degradation of the system. The methods are not intended to prove the suitability of the system for particular applications, but are intended to prove the capability of the combined equipment to generate ultrasonic beams according to the settings used. It gives strategies and acknowledgment criteria to confirming the execution of joined equipment (i.e. instrument, probes associated). The strategies portrayed are reasonable for clients working under on location or shop floor conditions. Its motivation is for the check of the right task of the framework preceding testing, and furthermore the portrayal of sound beams or confirmation of the nonappearance of degradation of the framework. The strategies are not proposed to demonstrate the reasonableness of the framework for specific applications, yet are expected to demonstrate the capacity of the combined equipment to produce ultrasonic beam as indicated by the settings utilized. The adjustment of the framework for a particular application is outside of the extent of part of ISO 18563 and it is planned that it be secured by the test methodology. This piece of ISO 18563 does not address the accompanying: encircling arrays; arrangement of aperture having an alternate number of elements; diverse settings for transmitting and accepting.

ISO (International Organization for Standardization) 19675:2017 specifies requirements for the dimensions, material and manufacture of a steel block for calibrating ultrasonic test equipment used in ultrasonic testing with the phased array technique. Characterizes the techniques for the estimations and confirmation of the phased array instrument inside the recurrence scope of 0,5 MHz to 10 MHz including the acknowledgment criteria[13] . Parts of this test can be likewise utilized for phased array instruments in computerized test frameworks, however then different tests might be expected to guarantee a palatable task.

ISO (International Organization for Standardization) 19285:2017 This document specifies acceptance levels for the phased array ultrasonic testing technique (PAUT) of full penetration welds in ferritic steels of minimum thickness of 6 mm which correspond to the quality levels. It indicates the estimation methods and acknowledgment criteria for the entire framework comprising of the instrument, probe and probe link preceding the application test to guarantee amend task [14]. The estimation strategies can be used nearby or on shop floor, they are not expected to demonstrate the reasonableness of the framework for specific applications. This part isn't expected to be utilized for encircling arrays arrangement of aperture having distinctive number of elements, diverse settings for transmitting and accepting and post processing signals.

BS EN (British Standard European Norm) 16392-2:2014: Non-destructive testing. Characterisation and verification of ultrasonic phased array equipment probes [15]. Verification, Probes, Test methods, ultrasonic, Terminology, Non-destructive testing

BS EN (British Standard European Norm) 16018:2011: Non-destructive testing. Terminology. Terms used in ultrasonic testing with phased arrays. Non-destructive testing, Ultrasonic testing, terminology, Probes, Piezoelectric devices, Test equipment [16]. Characterizes the estimations and confirmations of the qualities for linear phased array probes utilized as a part of contact or in immersion strategy inside a frequency range of 0.5MHz – 10MHz .

ISO (International Organization for Standardization) 13588:2012 determines the utilization of the phased array innovation for the semi or completely robotized ultrasonic testing of fusion welded joints in metallic materials of least thickness 6 mm. It applies to full infiltration welded joints of basic geometry in plates, funnels, and vessels, where both the weld and parent material are low-alloyed carbon steel

[17]. Where material-subordinate ultrasonic parameters are determined in ISO 13588:2012, they depend on steels having a ultrasonic sound speed of (5920 ± 50) m/s for longitudinal waves, and (3255 ± 30) m/s for transverse waves. It is important to consider this reality while inspecting materials with an alternate velocity. It gives direction on the particular capacities and confinements of phased array technology for the discovery, area, estimating and portrayal of discontinuities in fusion welded joints. Phased array technology can be utilized as a standalone innovation or in mix with other non-destructive testing (NDT) strategies or systems, for assembling examination, pre-benefit and for in-benefit assessment. It indicates four testing levels, each relating to an alternate likelihood of identification of defects. It grants appraisal of signs for acknowledgment purposes in view of either amplitude (proportionate reflector size) and length or height and length. It does exclude acknowledgment levels for discontinuities. It isn't contained for coarse-grained metals and austenitic welds; for robotized testing of welds amid the creation of steel items secured.

ISO (International Organization for Standardization) 11666:2018: This archive indicates two ultrasonic acceptance levels known as acceptance and full penetration welded joints in ferritic steels. This report applies to the testing of full penetration of ferritic steel welds, with thicknesses from 8 mm to 100 mm. It can likewise be utilized for different kinds of welds, materials and thicknesses, furnished the tests have been performed with important thought of the geometry and acoustic properties of the segment, and a satisfactory affectability can be utilized to empower the acknowledgment levels of this archive to be applied [18]. The ostensible frequency of probes utilized as a part of this archive is between 2 MHz and 5 MHz, unless constriction or prerequisites for higher determination call for different frequencies. It is vital to consider the utilization of these acknowledgment levels in conjunction with frequencies outside this range precisely.

2 Ultrasonic testing with phased arrays

2.1 Formats of ultrasonic data presentation

Ultrasonic information can be gathered and shown in various diverse arrangements. The five most basic configurations are known in the NDT world as A-scan, B-scan, C-scan, D-scan, S-scan presentations. Every presentation mode gives an alternate method for evaluating the region of material being reviewed. Current computerized ultrasonic scanning frameworks can show information in every one of the three introduction shapes all the while.

2.1.1 A-scan

A-scan is a portrayal of the ultrasonic pulse amplitude versus time of flight, or a waveform. The A-scan presentation shows the measure of received ultrasonic vitality as a component of time. The relative measure of received vitality is plotted along the vertical pivot and the elapsed time (which might be identified with the sound vitality travel time inside the material) is shown along the horizontal axis. Most instruments with an A-scan display enable the signal to be shown in its regular radio frequency form (RF), as a completely amended RF signal, or as either the positive or negative portion of the RF signal [19]. In the A-check introduction, relative intermittence size can be assessed by looking at the signal amplitude obtained from an obscure reflector to that from a known reflector.

Reflector profundity can be dictated by the situation of the signal on the horizontal sweep. An A-scan can be shown as a RF (radio-frequency) or bipolar-rectified signal in Figure2.1 colour encoding of the rectified A-scan signal amplitude includes another measurement and makes it conceivable to connect the probe movement arranges with the ultrasonic information as colour encoded amplitude in Figure2.2 Ultrasonic information with a RF show is typically encoded as grey scale pixels, with black and white limits from −100% to 100% to safeguard the phase data. Grey scale amplitude encoding is utilized as a part of TOFD setups and information investigation, as shown in Figure2.3.

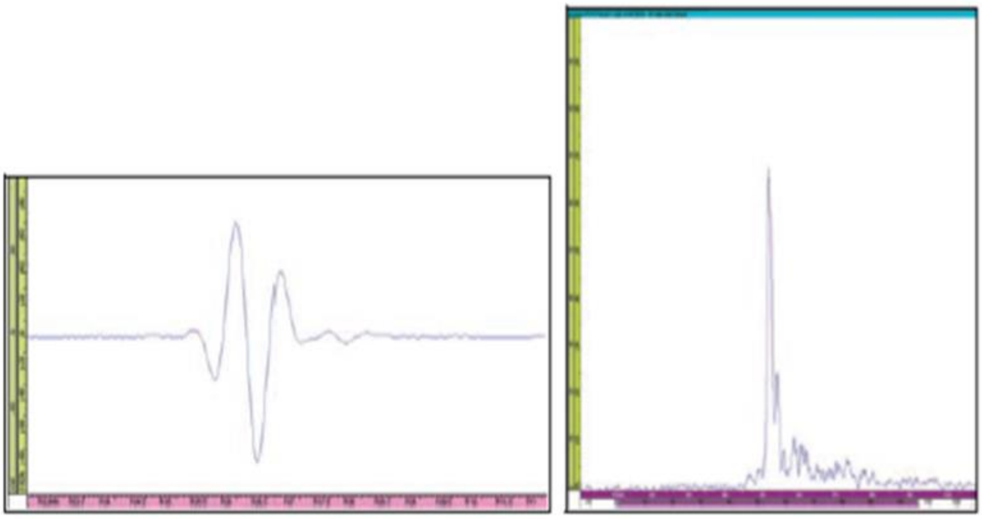


Figure 2.1 – A-scan representation: RF signal (left), rectified (right)

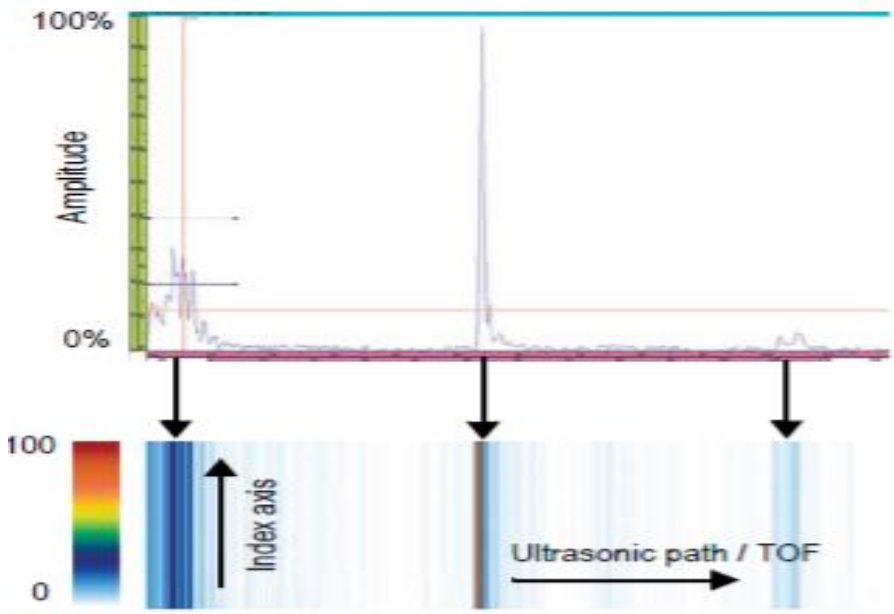


Figure 2.2 – Example of a colour-encoded rectified A-scan signal used to create a colour– coded B- scan

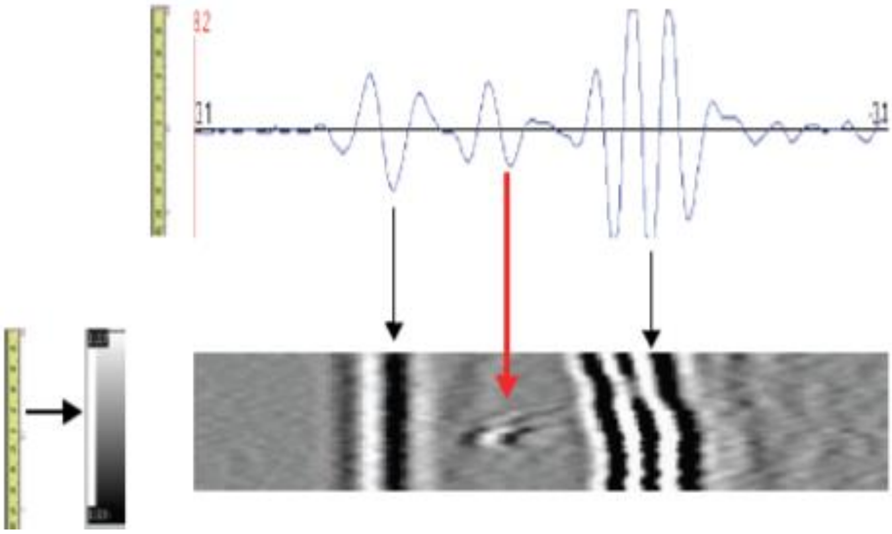


Figure 2.3 – Encoding of RF signal amplitude in grey-scale levels

2.1.2 B scan

The B-scan is a 2-D view of recorded ultrasound information. The B-scan presentations is a profile (cross-sectional) perspective of the test specimen. In the B-scan, the time of-flight (travel time) of the sound vitality is shown along the vertical axis and the straight position of the transducer is shown along the horizontal axis. From the B-scan, the profundity of the reflector and its surmised linear measurements in the scan direction can be determined. The B-scan is normally created by building up a trigger entryway on the A-scan. At whatever point the signal intensity is sufficiently enough to trigger the gate, a point is created on the B-scan [20]. Ordinary the flat hub is the scan position and the vertical axis is the ultrasound path or then again time; the axis can be turned around, contingent upon the required display as shown in Figure2.4. The position of the displayed data is related with the encoder positions right now of the acquisition [31]. Basically, a B-scan is a progression of stacked A-scans or waveforms. Each A-scan is represented by an encoder/time-base testing position as show in Figure2.5. The A-scan is amplitude colour coded (palette). Stacked A-scans, or a B-scans, is adequately the reverberate dynamic envelope in the axis of mechanical or electronic beam movement.

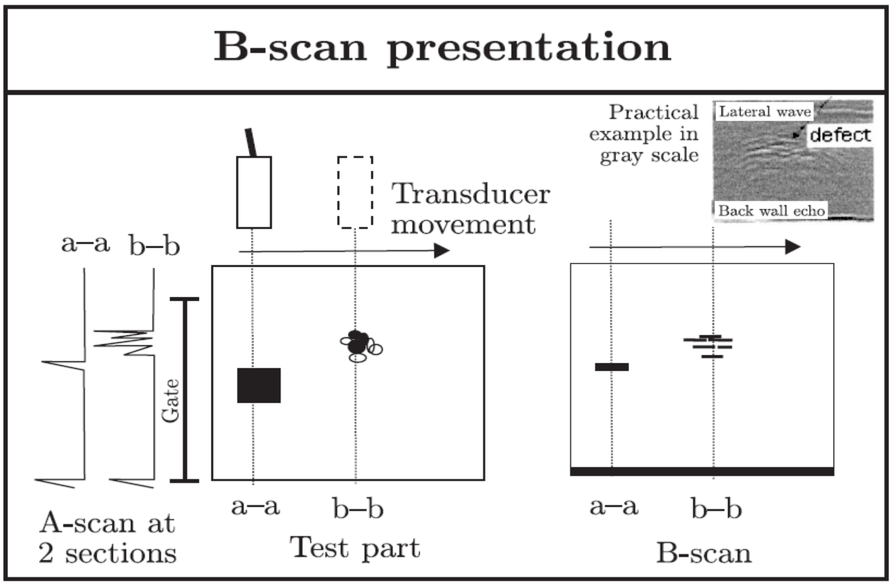


Figure 2.4 – Principle of B-scan acquisition

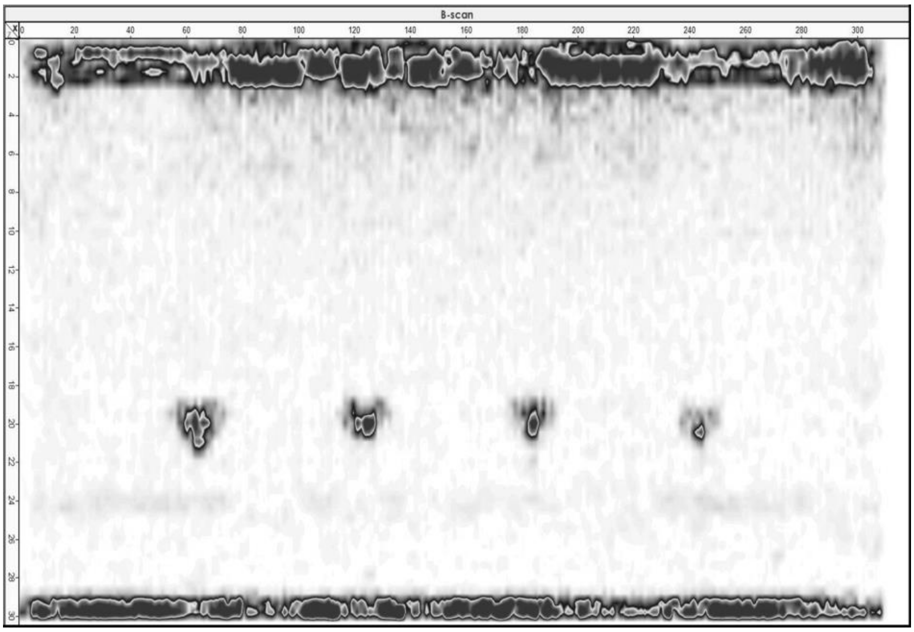


Figure 2.5 – Example of B-scan Presentation

All things considered, this show extends the defect image, and contorts the defect measure because of beam spread and more, different factors [34]. Some experience is required with cursor estimating to comprehend and adjust for this. In the event that the ultrasonic path is redressed for the refracted angle and postponement, the B-scan will represent to the volume-corrected side perspective of the investigated part, with scan length on the horizontal axis and profundity on the vertical axis in Figure2.6.

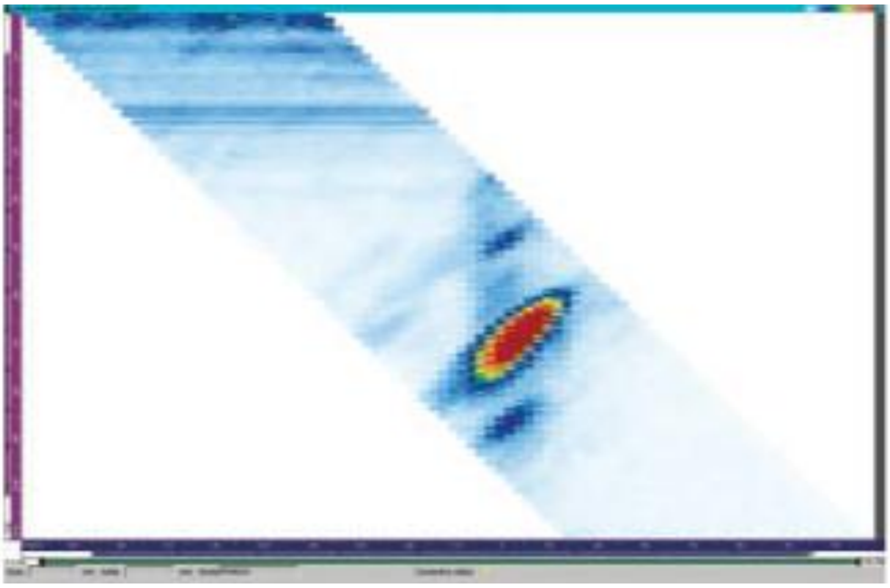


Figure 2.6 – Side (B-scan) view corrected for refracted angle

2.1.3 C-Scan

C-scan is a 2-D view of ultrasonic data appeared as a best or plan perspective of the test specimen. The C-scan presentation gives a plan-type view of the area and size of test specimen highlights. The plane of the image is parallel to the scan example of the transducer [32]. C-scan presentations are delivered with a mechanized information obtaining framework, for example, a PC controlled immersion scanning system. Normally, an information gathering gate is set up on the A-scan and the amplitude or the time of-flight of the signal is recorded at general interims as the transducer is scanned over the test piece. The C-scan presentation gives an image of the highlights that reflect and scatter the sound inside and on the surfaces of the test piece as shown in Figure2.7. High resolution scans can create exceptionally nitty gritty pictures. With regular ultrasonic system, the two axis are mechanical; with linear phased array, one axis is mechanical, the other is electronic. The situation of the showed information is related with the encoder positions during acquisition. As it was the greatest amplitude for each point is anticipated on this "scan index" plan view, actually known as a C-scan in Figure2.8.

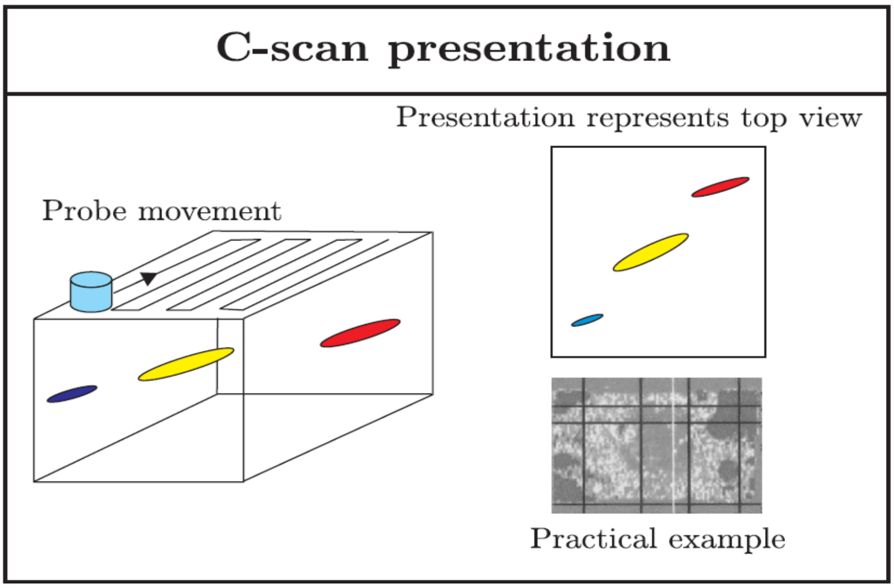


Figure 2.7 – Principle of C-scan acquisition

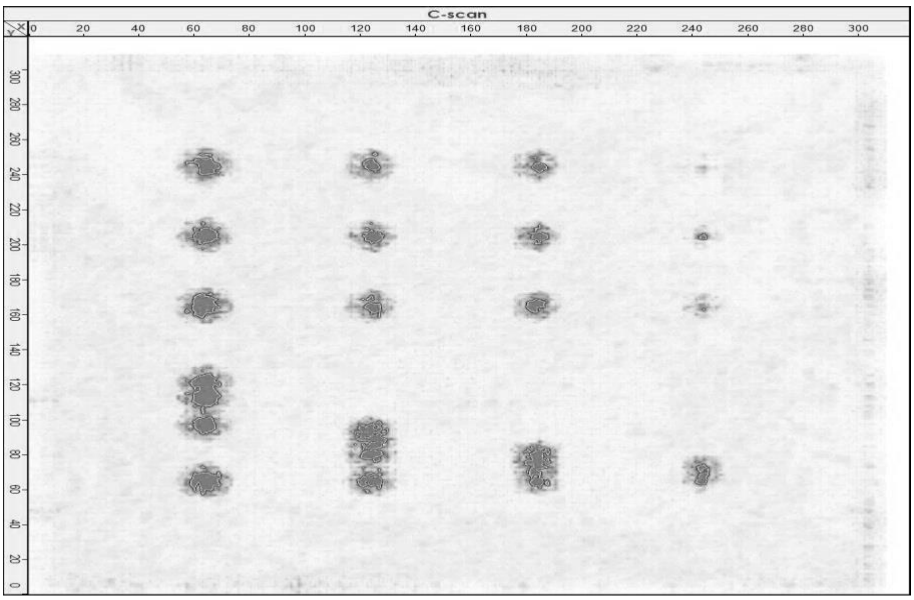


Figure 2.8 – Example of C-Scan top and side view

2.1.4 D-Scan

A D-scan is a two-dimensional graphical introduction of the information. It is comparable to the B-scan, yet the view is at the right-angle of the B-scan. In the event that the B-scan is a side view, at that point the D-scan is an end view. Both D-scans and B-scans are gated to just show information over a predefined profundity [25]. One of the axis is characterized as the index axis; the other is the ultrasonic path see Figure2.9. The B-scan shows examine axis versus time, though the D-scan shows index axis versus time. In the event that the ultrasonic path is revised for angle and delay, the vertical axis shows the profundity [24]. The end (D-scan) view is exceptionally valuable for information investigation utilizing the 2-D overlay (example) drawing especially for welds.

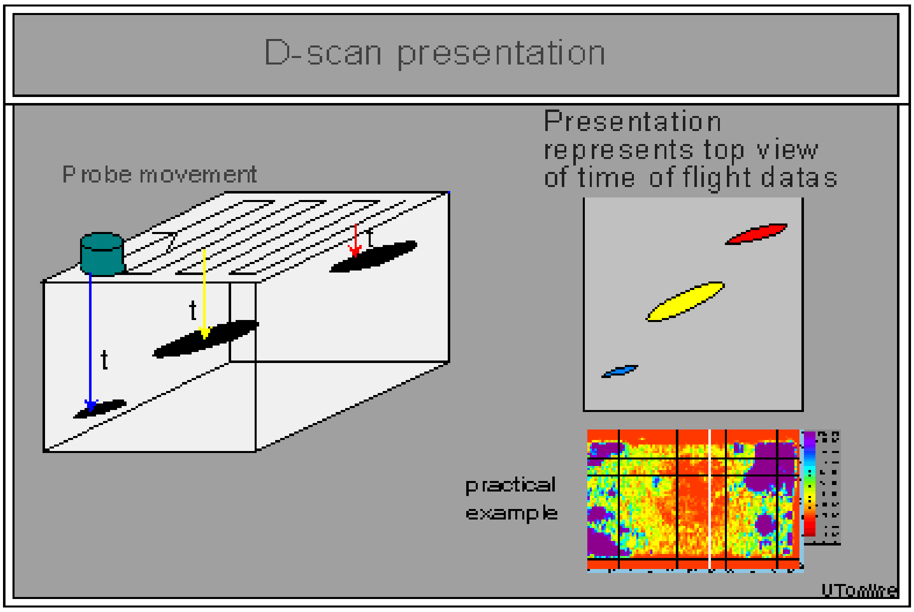


Figure 2.9 – Principle of D-scan acquisition

2.1.5 S-scan

S-Scan, Sectorial scan speaks to a 2-D perspective of every one of the A-scans from a particular channel rectified for delay and refracted angle. A typical of the S-scan clears through a scope of points utilizing the same focal separation and elements [25]. The even hub compares to the anticipated distance of the test piece width from the exit point for an amended image and the vertical axis corresponds to the profundity see Figure2.10 S-scan are special to phased array and can be longitudinal wave or shear wave, contact, immersion, or mounted on a wedge. S-scan

can likewise be shown as uncorrected or corrected, corrected S-scans demonstrate the genuine reflector positions, and are helpful for perception and image correlations.

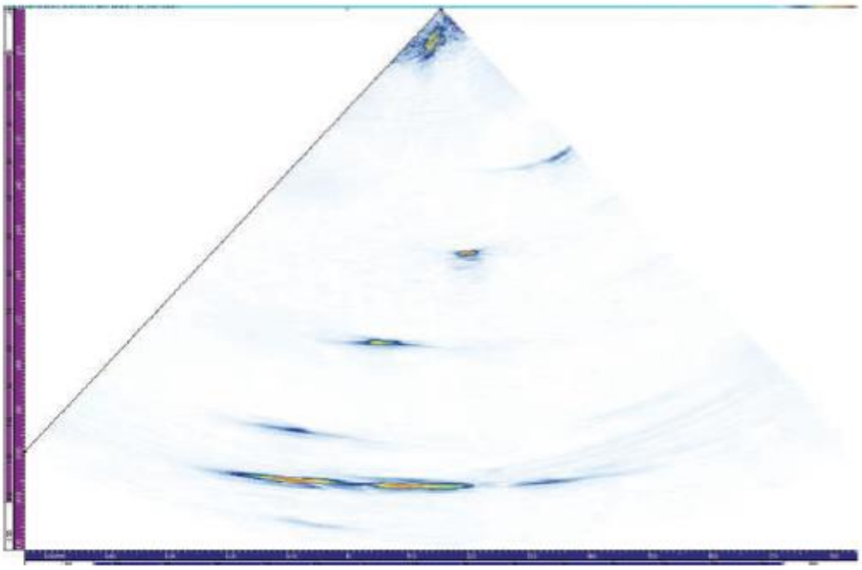


Figure 2.10 – Example of S- scan

2.2 Techniques for ultrasonic imaging with phased array

One of the biggest advantages of phased array application is the possibility to obtain the imagery of the internal structure of controlled object in one position of ultrasonic transducer. The benefits of phased array frameworks incorporate the capacity to perform electronic scanning of the ultrasonic beam, which can decrease review times by eliminating or diminishing the need move the probe. The unwavering quality of examinations can likewise be enhanced by decreasing the need to move the probe [23]. Phased arrays permit a wide range of spectrum of inspection that enhance execution, for instance, sectorial scanning and focalization after reflection off the back surface of the test specimen. The most progressive phased array system include tools, for example, dynamic-depth focusing. With real-time imaging, investigations are easier to perform and the quality of the estimations is additionally significantly moved forward. Since a large number of signals are caught and shown immediately, the battle that administrators regularly have in finding and visualizing defects on the screen is enormously reduced. More, the quantity of false alarms is diminished due to decreased administrator reliance, and information recording and traceability are made strides. The three general approach by ultrasonic imaging with phased array are as follows:

– Electronic focusing (EF)

– Total focusing method (TFM)

– Plane wave imaging(PWI)

2.2.1 Electronic focusing

The delay value for every component relies upon the aperture of the active phased array probe component, sort of wave, refracted point, and focal profundity. Phased array dosen't change the physics of ultrasonic; they are simply a technique for producing and receiving. There are three noteworthy computer controlled beam scanning patterns.

Electronic scanning initially called as linear scanning the focal law and delay is multiplexed over a gathering of active components see Figure.2.11 Scanning is performed at a steady angle and along the phased array probe length by gathering of active components, called a virtual probe aperture [24]. This is identical to a regular ultrasonic transducer performing out a raster scan for corrosion mapping see Figure.2.11 or then again shear waves inspection of a weld. If the off chance that an angled wedge is utilized, the focal laws make up for various time delays inside the wedge. Direct contact linear array probes may likewise be utilized as a part of electronic angle scanning. This set up is extremely helpful for distinguishing side wall, lack of combination or inward surface breaking cracks see Figure2.11. From all imaging modes examined up until now, the Sectorial scanning is one of a kind to phased array device. In a linear scan, every single focal law utilized a settled angle with sequencing apertures [22]. Sectorial scans, then again, utilize fixed apertures and steer through a grouping of angles. The configuration utilizes a calculated wedge to build the occurrence beam plot for shear waves, most usually in the refracted edge scope.

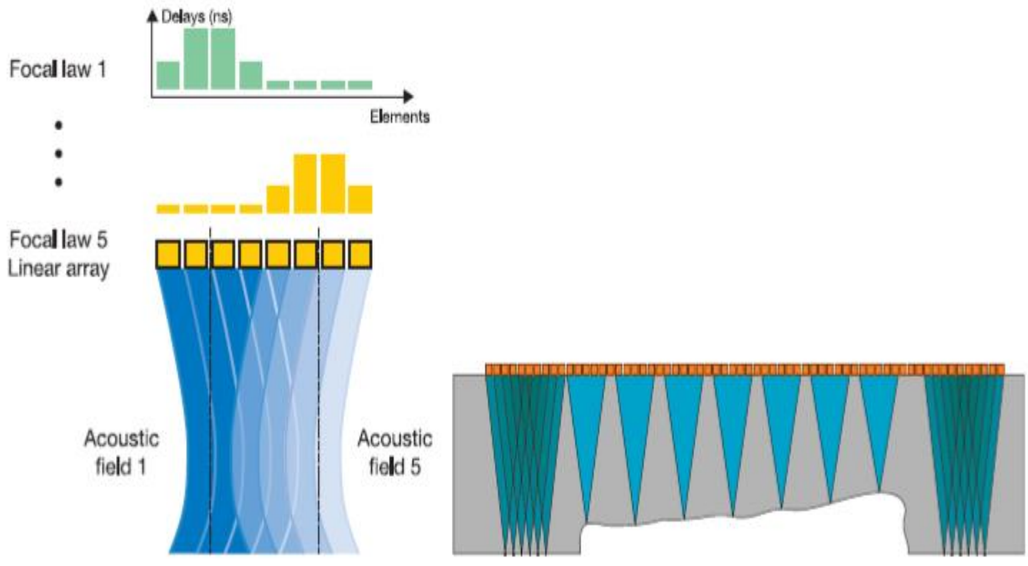


Figure 2.11 – Left: Principle of electronic scanning from zero-degree scanning. Right: schematic mapping for corrosion mapping with zero- degree electronic scanning.

Two fundamental structures are normally utilized. The most recognizable, extremely normal in restorative imaging, utilizes a zero degree interface wedge or to control longitudinal waves at moderately low edges, making an image demonstrating laminar and somewhat calculated defects. The second configuration utilizes an angled plastic wedge to increase the incident beam plot for shear waves, most usually in the refracted edge angle of 33° to 58° Figure2.12. This method is like conventional angle beam inspection, with the exception of that the beam clears through a range of angles instead of a simply single fixed angle dictated by a wedge [35]. Similarly with the linear scan, the image introduction is a cross-sectional photo of the assessed area of the test piece. The end client characterizes the point begin, end, and step determination to create the sectorial image. You will see that the aperture stays consistent, with each characterized angle creating a relating beam with attributes characterized by aperture, recurrence, damping and so forth. The waveform reaction from each angle is digitized and plotted identified with colour at the appropriate angle, constructing a cross sectional picture [33]. In fact, the sectorial scan is created continuously in order to persistently offer dynamic imaging with transducer movement.

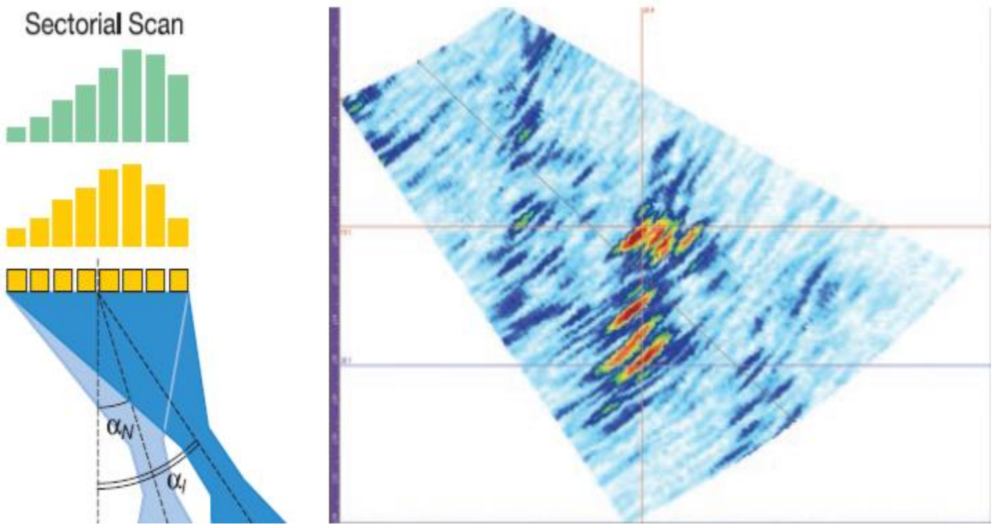


Figure 2.12 – Left: Principle of Sectorial scanning (S scan). Right: Sectorial scanning detecting a group stress-corrosion cracks from range33° to 58°.

This is extremely helpful for defect visualization and expands likelihood of detection, particularly as for randomly oriented imperfections, the same number of investigation angles can be utilized only once.

Dynamic depth focusing (DDF) takes full abilities of phased array technological to optimize resolution in depth whilst minimizing inspection time. To make sure constant resolution for the period of the thickness of the test specimen, one focal law is used in transmission and a number of focal laws are utilized in reception. For each and every delay regulation used in reception, the signal is digitized in a small time window situated on the corresponding focal depth [32]. The entire partial signals are then mixed to type the entire reconstructed sign, offering optimized resolution for the duration of the thickness of the specimen undergoing inspection. The talents of the Dynamic depth focusing (DDF) procedure is that all the depth measurements are performed within the same period of time fundamental to send and receive a single signal. Dynamic depth focusing (DDF) can be utilized along with digital scanning to supply a high-resolution picture. An illustration is given in the following Figure2.13. For a dynamic transducer which represents curved linear array, four impartial delay laws are used to focus the ultrasonic beam at four certain depths [23]. The blue bars displayed signify the delay laws used in reception.

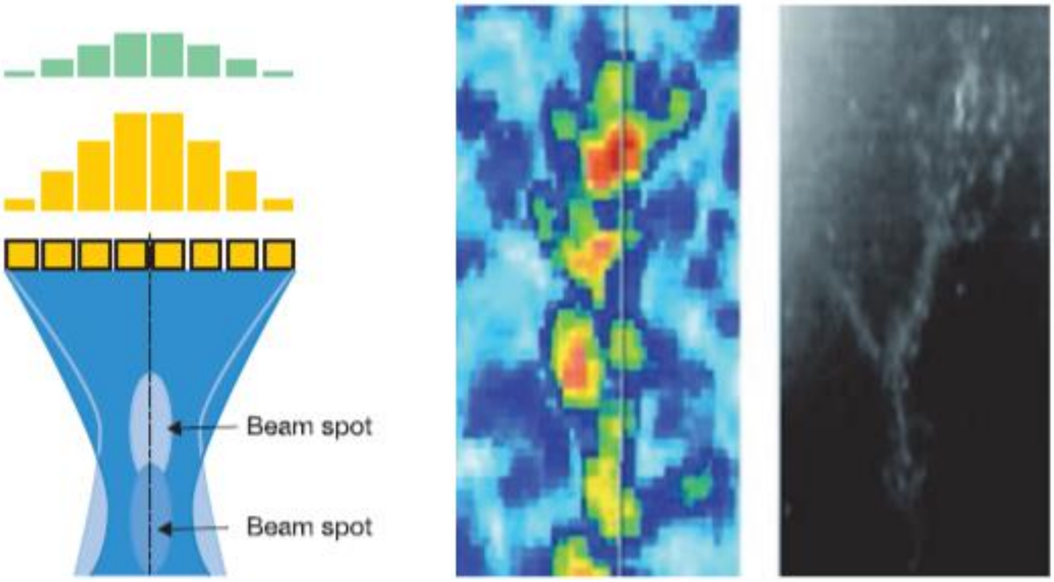


Figure 2.13 – Left: Principle of Dynamic depth focusing; Middle: A stress corrosion-crack; Right: Macro graphic comparison;

For every size position, the transmitted signal is focused at the core of the specimen thickness. In the time of a single pulse-echo shot, all four depths are being inspected with optimized resolution. Digital scanning is then used to translate the beam around the specimen.

2.2.2 Total focusing method (TFM)

It is portrayed concerning the various post processing technique for use in NDE that the best execution of the array was accomplished utilizing Total Focusing Method in which the beam is engaged at each point in the objective area [19]. This technique additionally enables the image to be stretched out past the angle of the exhibit while as it enabling the beam to centre focus. Among the conventional phased array, every array components are let go all the while to focus a beam with a settled core interest [31]. Utilizing Full Matrix Capture of all transmit get combinations permits imitating of any beam shaping plan through disconnected post-processing. This approach has some boundless outline suggestions for future NDE array systems. Full Matrix Capture is a data acquisition strategy that allows for the capture of every possible transmit-receive combination for a given ultrasonic phased array transducer [20]. Acquired data is processed in real-time using an optimised version of the Total Focusing Method algorithm which generates fully focused images from the Full Matrix Capture data. This new technique aims to increase the reliability of ultrasonic inspection leading to reduced costs and improved safety for industry.

$$I(x,z) = |\sum h_{tx,rx} \frac{\left(\sqrt{(x_{tx}-x)^2+z^2}+\sqrt{(x_{rx}-x)+z^2}\right)}{c_1}| \tag{2.1}$$

where: $I(x,z) -$ The intensity of the image.

Total focusing method the beam is engaged at each point in the target area as appeared in Figure2.14. It is still seem to be used in mechanical NDE frameworks because of a mix of the high number of transmit delay sequences and the computational power required to receive focussing [21]. The signals from every one of the components in the array are then summed to integrate a focus at each point in the matrix.

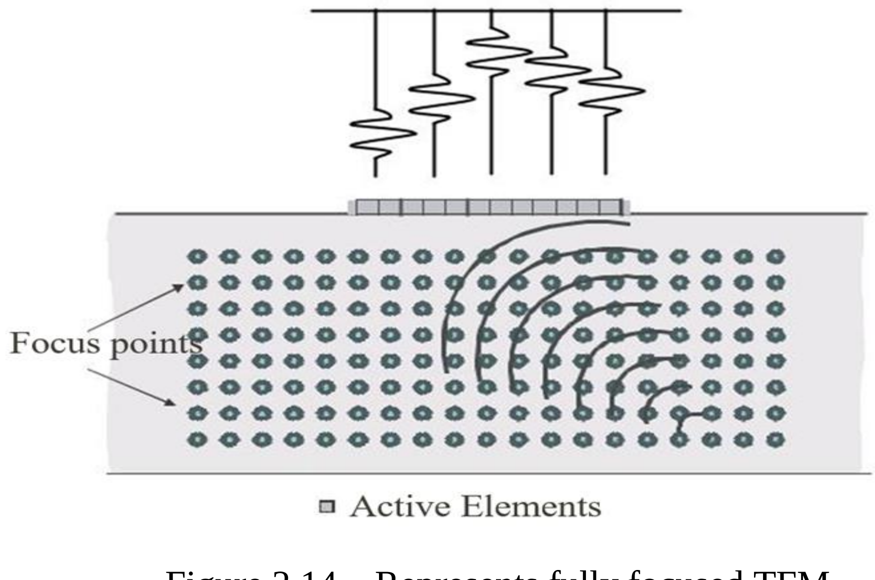


Figure 2.14 – Represents fully focused TFM

However, if the full matrix capture approach is received then the Total Focusing Method can be actualized in post-processing, the main restricting component being calculation time. The Total Focusing Method post-processing algorithm proceeds by first discretising into a grid. Linear Interpolation of the discretely inspected time domain signals is essential. This summation is completed for every conceivable transmitter– collector pair and hence utilizes the most extreme measure of data accessible for each point. This post-processing approach implies that a given beam is never physically accomplished in the test structure yet its impact is combined by a deferral and whole operation on the full informational index, or some part thereof. In the Synthetic Aperture Focusing Technique (SAFT) the power of each point in the image is the summation of the abundancy of each pulse echo motion at twice the time taken for the wave to proliferate from a component to that point. In the event that this point is related with a scatter, intelligible summation brings about a high intensity. This post-processing can be performed in either the time or recurrence areas [33]. Add up to Total Focusing Method depends on indistinguishable standards to Synthetic Aperture Focusing Technique (SAFT) with the exception of that information from each transmitter-receiver mix is utilized as a part of the imaging procedure. The Total Focusing Method is to give characterisation capacity. Scattering coefficient matrices that portray the point scattered by an imperfection as a component and scattered edges can be anticipated utilizing Finite Elements (FE) models or an assortment of investigative methodologies a half and half model is utilized to mimic the full matrix of information from an array review. It consolidates scattering coefficient matrix that model the wave– deformity interactions with a beam based model of wave proliferation. The Total Focusing Method calculation is expanded to perform imaging in a multi-layered structure in which both longitudinal and shear waves are considered and imaging includes maybe a couple reflections [21]. The scattered abundancy and Signal to Noise Ratio (SNR) removed from the multi-mode Total Focusing Method images are then used to evaluate the execution of this weld examination.

Advantages of Total Focusing Method:

– It has the ability to focus everywhere.

– Total Focusing Method is less sensitive to positioning and easier to use.

– Total Focusing Method allows characterization of small defects and complex defects

– Total Focusing Method can potentially lead to lower amplitude echoes when the size of the elements is relatively small.

– Total Focusing Method has potential to perform reconstruction below complex surfaces such as a weld. This opens the way for inspections for which the surface is not known and inspection of welds from the weld underneath.

– Estimating can be workable for little deformities for which it is commonly impractical to get a diffraction.

– A Total Focusing Method reproduction is performed in a semi-infinite medium utilizing the velocity of water

– The profile of the section surface is separated by recognizing the most extreme of the each column in Total Focusing Method picture

– Utilizing Total Focusing Method anyone can even recognize the imperfections even those situated underneath the irregular piece of the entry surface.

– The versatile procedure was then connected to the thickness estimation of a welded pipe.

2.2.3 Plane wave imaging

In ultrasound imaging with arrays the frame rate is restricted by the quantity of insonifications of the reviewed medium. In the point of confinement, a single omnidirectional or plane wave insonification would give the most extreme frame rate [28]. Be that as it may, since focusing is connected in gathering just, this technique yields a poor picture quality. With contrast, multi-insonification strategies, for example, Plane Wave Imaging (PWI) have the possibility to provide quality imaging, despite the fact that they require more procurement time. It transmits ultrasonic elements by phased array and do it simultaneously by s element by phased array .

simultaneously reception of echo of elements by elements of phased array. Ultrasonic imaging with high frame rates is of great interest in Non-Destructive Testing (NDT) to perform fast inspections [27]. The Plane Wave Imaging method is applied to immersion-testing configurations (plane or complex water/steel interface between the probe and the image area) and to different imaging modes (imaging with direct or half-skip wave paths) according to the type of defects (point-like or extended crack-types defects). Plane Wave Imaging method is very promising for NDT applications as it provides images with quality equivalent to images but with fewer transmissions [29]. The method has been evaluated and validated in case of plane and irregular surfaces, and by using direct or half-skip imaging modes. In post-processing, the beginning stage is the full matrix of array information. The B-scan imaging algorithm entireties the parts of the matrix relating to the time area signals from the individual components in every aperature. The power of a point in the plane wave imaging is given by the post-processing of registered ultrasonic is done according to the following formula and is also explained in the below Figure2.15. In order to overcome the number of adjacent elements, termed as aperture, are pulsed simultaneously as seen in Figure2.16 to produce planar beam. The time taken for domain signals from every element in the aperture are then summed to single time domain signal [27]. This approach has same performance from a plane transducer of same size from the opening. The opening is then electronically shifted along the length of the exhibit, with the time space signals got from each progression being joined to shape the last B-scan image. In post-handling, the beginning stage is the full framework of exhibit information. The B-scan imaging calculation entireties the parts of the matrix comparing to the time space signals from the individual components in every gap [30]. Results for various opening positions are registered from various parts of the lattice.

$$\tau(x_1, x, z) = \left(z + \sqrt{z^2 + (x - x_1)^2}\right)/c, \quad (2.2)$$

where: $c -$ is the speed of sound that we assumed to be constant in the medium;

x,z – coordinate of the point in the medium;

x_1 − coordinates of the element of phased array.

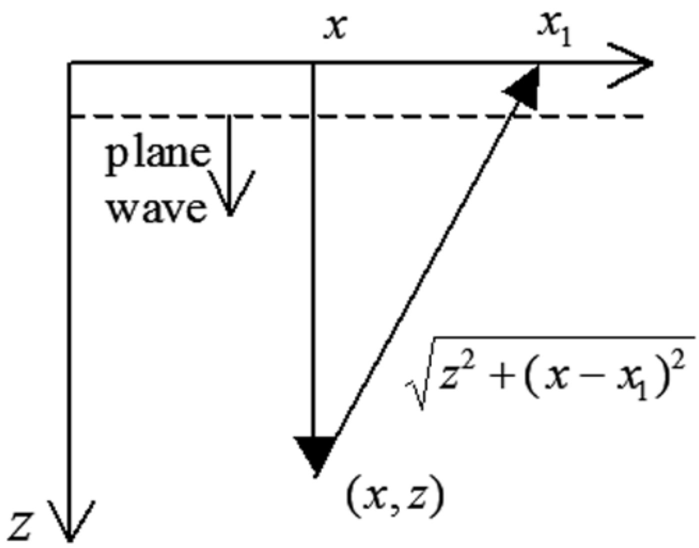


Figure 2.15 – Time delays for a plane wave insonification,

On that off chance that utilized alone, a single array element would have poor parallel determination because of the beam divergence and low sensitivity because of the small element size.

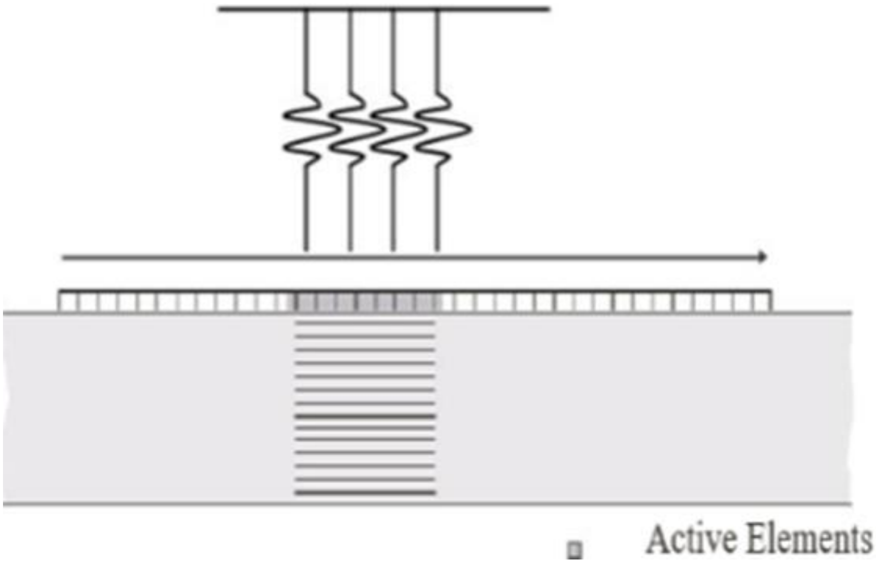


Figure 2.16 – Plane B – scan

3 Analytical comparison of techniques of ultrasonic imaging with phased arrays by CIVA UT software

3.1 The description of CIVA UT software

Ultrasonic modelling and simulation are increasingly broadly utilized by different techniques of modern NDT. The applications are various and demonstrate an incredible assortment: help for conclusion, information reconstruction, execution exhibition, probes design and inspection parameters settling, virtual testing and so forth. The CEA (the French Atomic Energy Commission) is firmly engaged with this advancement with the improvement of the CIVA mastery stage which accumulates in a similar programming propelled handling and demonstrating apparatuses. In the point of satisfying prerequisites of a serious utilize the decision has been made to for the most part receive semi-analytical approximated techniques. The wave propagation modelling depends on a necessary definition of the radiated field and applies the supposed pencil strategy. The demonstrating of beam imperfection communication and echoes arrangement systems apply approximated hypotheses, for example, Kirchhoff approximation or GTD [34]. Throughout the years and with progressive forms of the product, this approach is enhanced by adjustments and changes of the current models or by new models, keeping in mind the end goal to expand the field of relevance. These days numerical simulation assumes a part in an expanding scope of NDT applications. The targets pursued by the NDT administrator utilizing simulation are extremely different from an application to another. Simulation is ordinarily used to imagine strategies and exhibit their exhibitions requiring low cost. With the advancement of phased array applications, simulation additionally turned into a fundamental device for planning and driving probes. Simulation likewise permits "virtual testing", which can be connected to consider the controllability of segments at the beginning periods of their origination. Finally simulation is useful for deciphering examination comes about and can prompt reversal calculations and programmed determination. Since the start of the nineties the CEA (French Atomic Energy Commission) is emphatically engaged with simulation for NDT by building up the CIVA programming, a plat-shape assembling in a similar domain handling, imaging and simulation tools and accordingly permitting immediate and simple examinations amongst trial and processed information. For full-filling the prerequisite of calculation times compatible with practical use in industrial setting the decision of semi-analytical techniques instead of completely numerical strategies has been done and research is constantly accomplished in the research facility keeping in mind to extend the appropriateness of these techniques to constantly more intricate circumstances [32]. Throughout the years the consequences of this modelling activity are incorporated in successive renditions of CIVA in the point of satisfying prerequisites of clients an example of CIVA scanning ins shown in the Figure3.1.

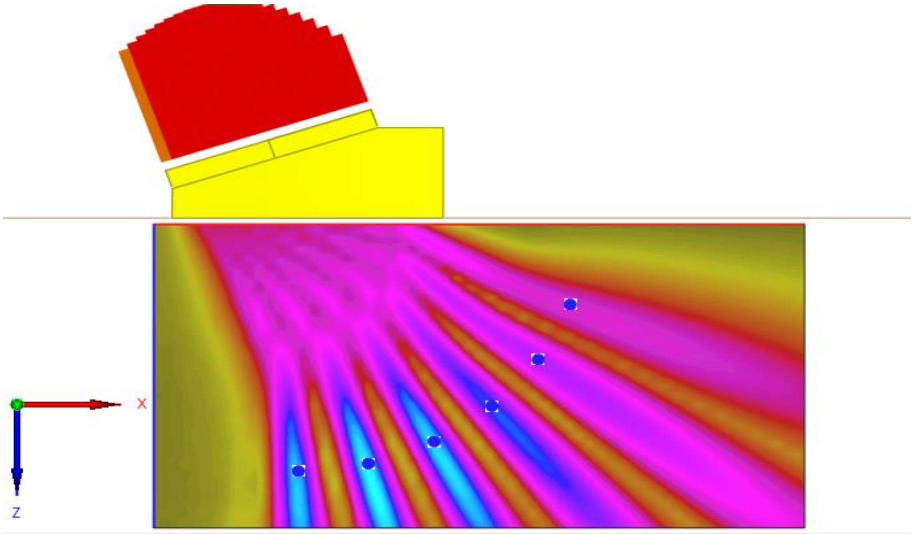


Figure 3.1 – Example of CIVA Scanning

Ultrasonic modelling may react to different destinations, consequently different modules in view of a similar math portions have been actualized in CIVA. Module devoted to the calculation of ultrasonic fields for one position of the test, module reproducing the consequence of the phased array module for registering delay laws, module showing the scope rate, finally reconstruction calculations for enhance the limitation and characterization of the imperfections offering ascend to the recognized echoes, beams with multiple shots of phased array probes as shown in the Figure3.2 . Keeping in mind the end goal to make less demanding the utilization of the different recreations modules, they all are associated with a similar realistic clients interface condition. The examination scene is viewed in a 3D show window and the GUIs devoted to the segment and the probe are normal to every one of the modules. Other than to this normal piece, are GUIs particular to every module [34]. One key issue in ultrasonic NDT simulation is the ability of codes to manage extremely different geometries of parts, some of the time complex, and frequently portrayed by CAD. To give simulation apparatuses in virtual CAD environment is undoubtedly of awesome down to significance and CIVA has been associated with a CAD library. This association makes conceivable ultrasonic simulation on non-authoritative geometries: Besides parametric segments, for example, planar, parts, tubes, elbows or spouts, the CIVA client can stack a 2D or 3D CAD file in a standard configuration (STEP, IGES).

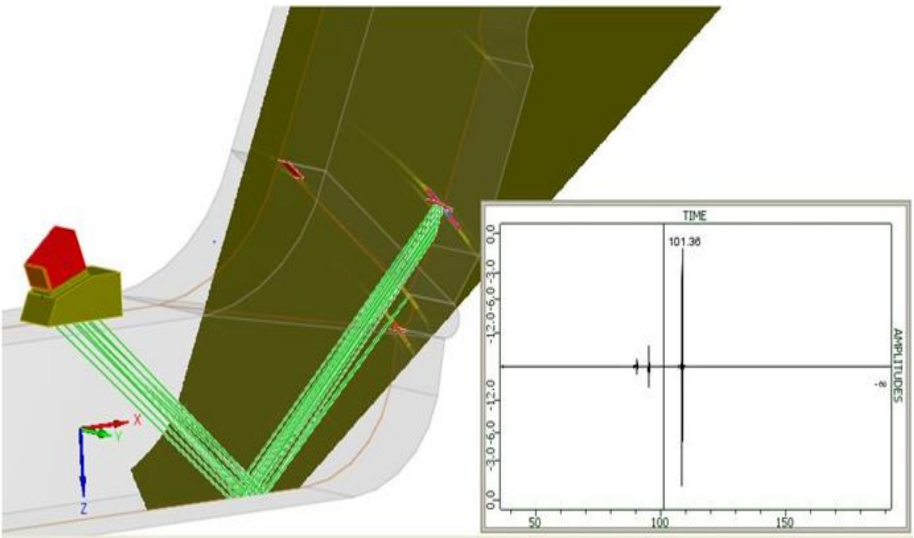


Figure 3.2 – Beam with multiple shots PA probe

Throughout the years, in the system of various coordinated efforts, a few models and information handling calculations created in different research facilities or colleges in France and Europe have been incorporated in CIVA. Quite a long while back, to sum up and make simpler such associations programming building works have been propelled in CIVA with the point of proposing a software platform permitting to coordinate, pleasantly, different reproduction codes. "NDT programming components " have been made which guarantee a santadard interface between the basic CIVA and numerical codes. The fundamental motivation behind this stage approach is to broaden the utilization of numerical reproduction in modern setting by offering to end clients correlative reproduction devices and by encouraging the information trade between models to advance approval and code benchmarks [31]. With progressive adaptations of CIVA, demonstrating progresses are incorporated keeping in mind the end goal to enhance the simulation exhibitions and to extend the domain of utilizations. To assess the dependability of simulation results and furthermore to decide the space of legitimacy of the codes are issues of the best significance. Reasonable setups regularly include a few influent parameters whose particular impact on the exactness of the model expectations must be studied. Furthermore, in a few circumstances it is difficult to acquire precise test estimations on superbly well.

CIVA enables the client to process delay laws and sequences of delay laws for standard and progressed phased array methods:

– normal or independent definition for transmitting and accepting components[37];

– Electronic scanning, straightforward or advanced (e.g. variable aperture at transmission or gathering).

Delay laws can be processed for specimen of subjective geometry and materials from the least difficult to the most exceptional arrangement:

– Sectorial examining ;

– Concentrating on one or several arbitrary points;

– Electronic scanning ;

– Utilization of non-uniform amplitude laws ;

– Utilization of dynamic delay laws.

CIVA additionally proposes Synthetic Focusing with the Total Focusing Method calculation that can be connected to permit ideal recreations of flaw echoes and specimen boundaries. This handling permits, from a securing record or a phased array simulation, the reconstruction of the image by joining signals so as to have the best concentrating on a given zone [36]. Primary related procurement types are Full Matrix Capture or Plane Wave Imaging acquisitions. Total Focusing Method should be possible for a single position of the transducer or related with a mechanical scanning. For this situation, Cumulated or Sliding Total Focusing Method recreation modes are accessible. Adaptative Total Focusing Method (ATFM) can likewise be tried in CIVA.

Examination Simulation module simulates the beam defect interaction and predicts the amplitude and the time of flight of different echoes: direct echo, corner effect, tip diffraction echo, etc. The quantity of skips has no restriction. It can likewise compute echoes scattered back by the geometry (backwall, entry surface and inside specular interfaces echoes), considers mode changes and at times creeping waves.

For TOFD configuration, direct tip echoes produced by the edge of the deformities are simulated and also lateral waves. The rundown of modes enables the client to pick which modes to ascertain [36].

To comprehend and evaluate the effect of influential parameters on a NDT assessment, parametric investigations in CIVA are especially adopted since it is simple and quick to accurately change and screen parameters. In light of a first arrangement of calculations, meta-models can likewise be figured in CIVA, which gives broad new outcomes to the client progressively, and also intense investigation tools, for example, multi parametric analysis and sensitivity examination to assess the relative effect of influential parameters.

POD calculations (Probability of Detection) are accessible, in view of the accounting of questionable input parameters. Single or Array of POD curves can be plotted inside CIVA.

Results are given as established ultrasonic information (A-Scan, echodynamic curves) or further developed images (B-Scan, C-Scan, S-Scan, E-Scan, and so forth.) that can be recreated and superimposed on the work piece, permitting an ideal comprehension of physical wonders. Results can be adjusted versus a reference flaw in a block. Time Corrected Gain can be additionally connected from DAC curves.. Mode identification tools permits recognizing the diverse modes that adds to an echo. Amplitude or Distance estimation tools are incorporated.

3.2 Computer simulations

3.2.1 Parameters of the applied simulations

The metal specimen used for the experiment has a rectangular shape, which is made of steel. The material consist of isotropic layer, density of 7.8 $g.cm^{-3}$, longitudinal wave velocity of 5900 ms^{-1} and transverse wave velocity of 3230 ms^{-1} . The specimen is shown below in Figure 3.3.

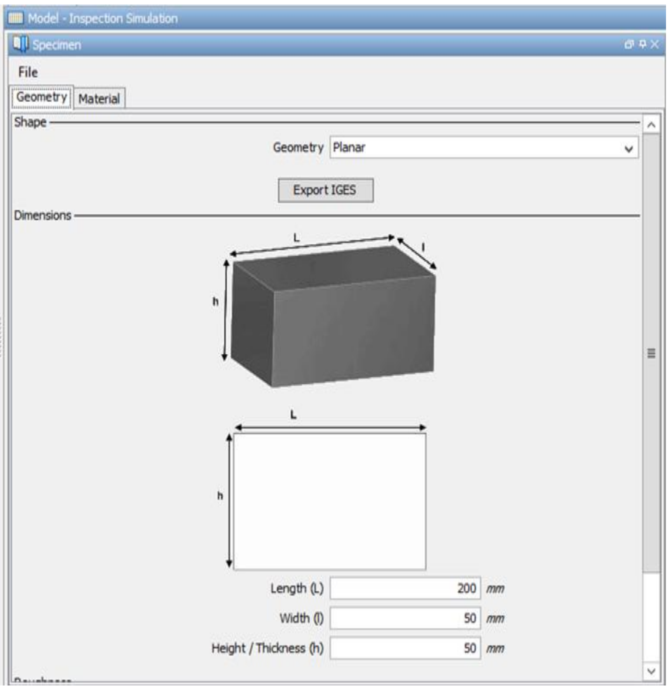


Figure 3.3 – Geometry of the specimen

Parameters of the transducer, the number of elements of linear phased array consists of 16 elements as shown in the Figure3.4. The orthogonal dimension is 20mm, incident dimension is 9.5mm, gap between the elements is 0.1mm and width of the element is given by 0.5mm. The parameters of the phased array probe is shown in the Figure 3.4.

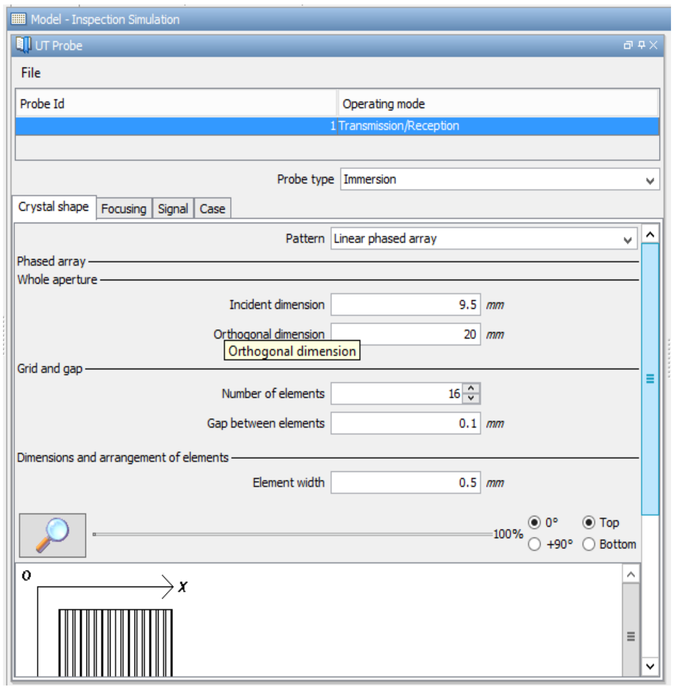


Figure 3.4 – Parameters of the transducers

Focusing is given by flat surface type. The probe type is given as immersion with signal for center frequency is 5MHz whose bandwidth is 50% at -6db, sampling with number of points is 512. The details regarding the signal and other description has been shown in the below Figure3.5.

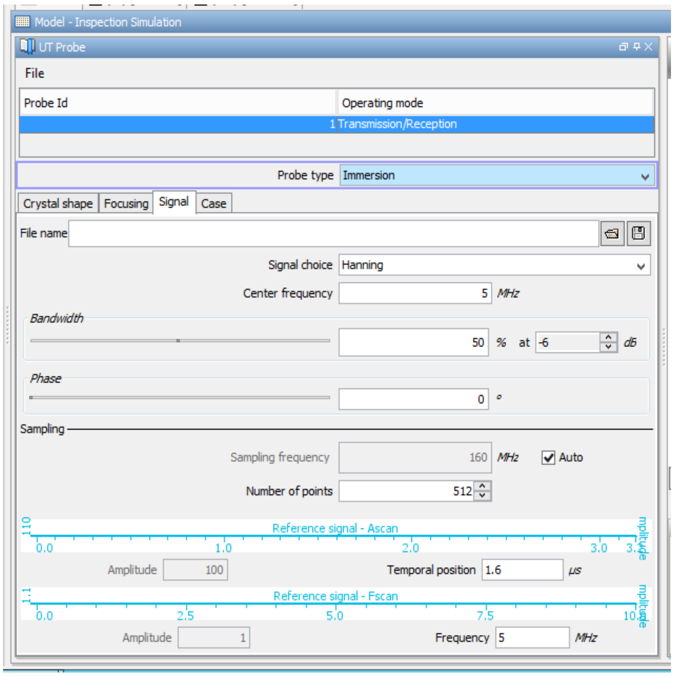


Figure 3.5 – Criteria about the probe

Modes used for data collection: Phased arrays permits a wide range of spectrum of inspection that enhance execution, for instance Total focusing method, Plane wave imaging and Electronic focusing. Utilizing Full Matrix Capture of all transmit get combinations permits imitating of any beam shaping plan through disconnected post-processing. Using Plane wave front full array technique the mode of operation of plane wave imaging was carried out. Regarding Electronic focusing we used a technique called as Multi point focusing which dosen't need the post processing technique as it is needed for Total focusing method and Plane wave imaging. Versatile coding technique was used for Total focusing method and Plane wave imaging for analysing the performance of the above said techniques in different ways. Since Electronic focusing is a virtual focusing technique not a physical focusing post processing was carried out only in total focusing method and plane wave imaging. In Electronic Focusing we don't need focusing through algorithm.

Types and position of the flaws: Geometry of the flaw is given by side drilled holes with a diameter of 1mm and length 50mm. Positon is varied by varying the angle as 0°, 15°,30°,45° and 60°. Distance is same for all 10mm the reason is because of near field is limited by 19mm. The positioning of flaw was done by varying with angle and distance which mentioned above. Number of Modes of identification is given by 5. Outside the near field electronic focusing doesn't provide a good result and it is not good [35].

The nearfield distance can be estimated according to the following formula:

$$N_0 = \frac{A^2 f}{4v_1}, \tag{3.1}$$

where, A – Probe active length (active aperture);

f – Ultrasound frequency;

v_1 – Velocity in medium (water).

Data was extracted from CIVA and processed using MATLAB. Various codes was used for the analysing the performance of all the considered techniques. In the case Total Focusing Method and Plane Wave Imaging it includes the post-processing and obtained imageries analysing whereas for Electronic focusing only imagery analysis was developed.

API (Array Performance Indicator) is a comparison criteria in order to estimate the results of the simulations, Figure3.7 shows schematically the idea of Array Performance Indicator for a basic Gaussian formed point spread function. The Array Performance Indicator is a dimensionless measure of the spatial size of a point spread function. It is characterized as the zone, inside which the point spread function is more noteworthy than a specific division of its most extreme esteem, standardized to the square of the wavelength**.**

$$API = \frac{A_{6db}}{\lambda^2} \tag{3.2}$$

Where, API $-$ Dimensionless measure of the spatial size of a point spread function;

A_{6db} $-$ Area, within which the point spread function is greater than $-6db$;

λ^2 $-$ Reflector position.

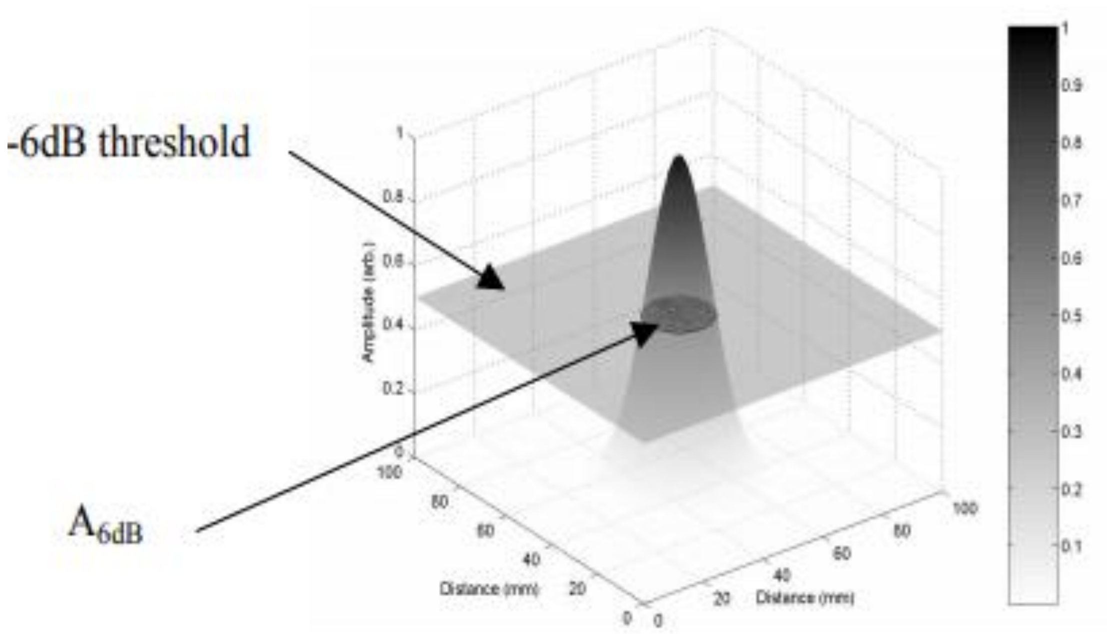


Figure 3.7 – Representation of API.

3.2.2 Results and discussion

The results of simulations which are estimated by the application API values are presented in Tables 3.1 – 3.2.

Table 3.1 – API values of the imageries of the flaws which are located on the distance of 10 mm relatively to the centre of the transducer by using considered techniques

Angle between the flaw and central line of the transducer	Array Performance Indicator (API)		
	Electronic Focusing	Total Focusing Method	Plane Wave Imaging
0	1.113	1.127	1.314
15	1.077	1.041	1.357
30	1.091	1.106	1.536

45	1.163	1.314	1.903
60	1.536	1.594	3.210

Plane wave imaging is not effective with the increase of the angle between the flaw and central line of the probe which will result in poor quality of imaging. Electronic focusing and TFM doesn't have such problem. So, in the case of Electronic focusing results for the flaws were obtained in the point of focusing. In order to see the changes in results in the case of the deviation between the position of the flaw and point of focusing we conducted the additional simulation in which you increase the deviation between the position of the flaw and focusing point with the step of 1mm for electronic focusing. So in order to obtain a better quality of imaging we do the simulation only within the examining limit.

Table 3.2 – API values of the imageries of the flaws which are located on the distance of 10 to 20 mm relatively to the centre of the transducer by using electronic focusing techniques.

The deviation of the flaw from the focusing point	API
	Electronic Focusing
1mm	1.113
2mm	1.077
3mm	1.314
4mm	1.486
5mm	1.788
6mm	1.809
7mm	1.838
8mm	2.291
9mm	2.865
10mm	3.167

Since electronic focusing can be done only in near field if done at far field more deviation occurs which will cause of poor quality of imaging. As you can see in the Table 3.2 the quality of the imaging gradually increases which results in poor quality of imaging in electronic focusing. It is connected with the possibility to make the imaging only in nearfield. In this case the distance was chosen as 10mm in order to make the comparison of electronic focusing in far field. We can see that the quality of imaging decreases as it goes more further from the point. So the nearfield is limited at a distance of 19 mm. TFM (Total focusing method) is able to make the imaging in nearfield as well as in far field.

Table 3.3 – Dependence of the API indicator of the flaw for the imageries obtained by using TFM and distance between flaw and the probe.

Distance of the flaws from centre	API
	TFM
10	1.127
20	2.190
30	3.174
40	4.064
50	4.948

In the case of Plane Wave Imaging the quality of the imaging strongly decreases outside the aperture. For Plane Wave Imaging, imaging is not effective outside the zone under array. For Electronic Focusing it’s not effective in far field. Total focusing method dosen’t have this problem. Total focusing method and electronic focusing have the same results for all the considered flaws. However if flaw is situated outside the focusing point the quality strongly decreases in electronic focusing. In automated systems for non-destructive testing, it is more appropriate to use Total Focusing Method flaw detectors. For Total Focusing Method and Electronic Focusing the angle of flaw dosent affect as it affects for Plane Wave Imaging. In electronic focusing the output obtained is where the flaw is exactly situated which is directly on the area. If the deviation is further or away from the value of the electronic focusing method is not good. So Plane Wave Imaging and electronic focusing dosen't have good result in far field, Total Focusing Method provides good imaging in various deviation. Total Focusing Method is less sensitive to positioning and easier to use. Total Focusing Method superior compared to electronic focusing because of its ability to focus everywhere. Fully focused images can be obtained through Total Focusing Method. High sensitivity to small flaws. High resolution. Signal-to-noise levels equivalent to phased array. Real-time inspection. Ease of inspection setup as no complicated focal laws involved. Ease of interpretation.

Some of the disadvantages of Total Focusing Method is the calculation and simulation time for Total Focusing Method compared to Plane Wave Imaging and Electronic Focusing is more. However, we see that Total Focusing Method can potentially lead to lower amplitude echoes when the size of the elements is relatively small.

3.3 Experimental part

3.3.1 Experimental setup

In order to confirm the results obtained via the computer simulations real experiment was conducted. The equipment which was used was as close as possible to parameters applied in simulations.

The probe Olympus 5L16-A1 which is shown in Figure 3.8 is designed to have a low-profile probe/wedge combination for easier access in restricted areas. A wide selection of wedges is available to suit any angle beam application. These probes are used for manual or automated inspection of 6.35 mm to 38 mm thick welds and the inspections of castings, forgings, pipes, tubes, and machined and structural components for cracks and welding defects.

Figure 3.8 – Ultrasonic Probe (Olympus 5L16-A1)

Advantages of the probe include, they are designed to have a low-profile probe and wedge combination for easier access in restricted areas. Wave layers with acoustic adaptation to rexolite. Captive anchoring screws are provided with the probe. A wide selection of wedges is available to suit any angle beam application.

Typical applications is A1, A11, and A12 Probes Manual or automated inspection of 6.35 mm to 38 mm (0.25 in. to 1.5 in.) thick welds.

Inspections of castings, forgings, pipes, tubes, and machined and structural components for cracks and welding defects

Data about probe Frequency is 80MHz. The number of Elements is 16. Pitch size is given by 0.60mm. The active aperture is 9.6mm. Elevation is 10.0mm. External Dimension length is 23mm (0.91 in.). External Dimension width is 16mm (0.63 in.). External Dimension height is 20mm (0.79 in.).Speed of Ultrasound is 5900m/s.

The acoustic unit is connected to the electronics module OPTUS, which was developed by I-Deal Technologies GmbH (Germany) as shown in Figure3.9. This unit allows the ultrasonic data sampling in the case of single element probes, Linear and Matrix phased arrays application. The unit has a transmitter\receiver 128 channels module that could be used for both single- and multichannel measurements.

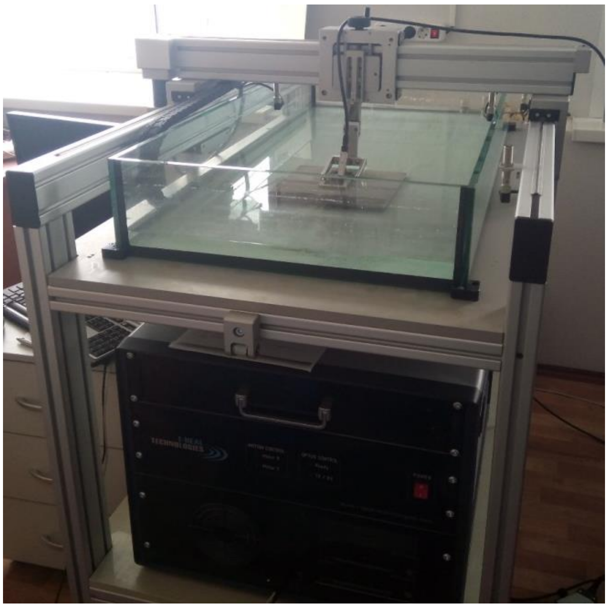


Figure 3.9 – Electronics module OPTUS

Thus, this unit can be used for a wide range of automated ultrasonic inspection tasks, e.g. the ultrasonic fingerprinting

Testing specimen is rectangular in shape which is made up of steel. The type of the flaws in steel block is side drilled holes. According to the specimen each of the flaw has the following coordinates. The dimensions of the flaws is 1mm in diameter. The coordinates of the position of the flaws is shown is the Table 3.4.The metal specimen which shows the position of the flaws is shown below in the Figure 3.10.

Table 3.4 – Describes the position of the flaws in the specimen.

Flaw	A	B	C	D
X coordinate, mm	-7.5	0	6.5	10
Z coordinate, mm	7.5	11.25	9.75	5.5

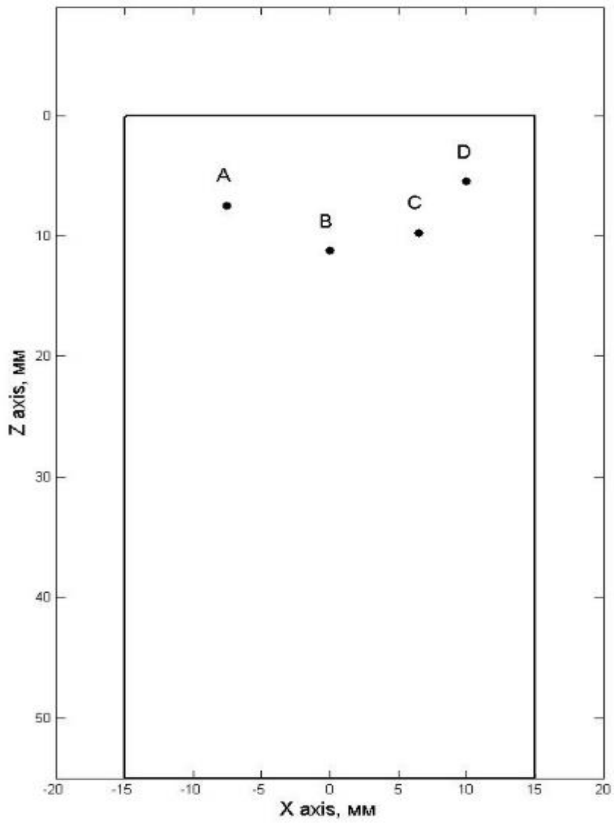


Figure 3.10 – Position of the flaws in the specimen.

The data registered by the electronic unit was used as initial data for the algorithm which was implemented in Matlab. For the experimental results verification computer simulation in CIVA was conducted with the parameters close to conditions of experiment.

Total focusing method was implemented in Matlab. The data obtained through the experiment conducted through experiment is compiled into data which is then fed in Matlab. Sampled data and simulated data were used as an input data for the algorithm. The output of the image obtained through experimental and simulation setup is shown in Figure 3.11 and 3.12 respectively.

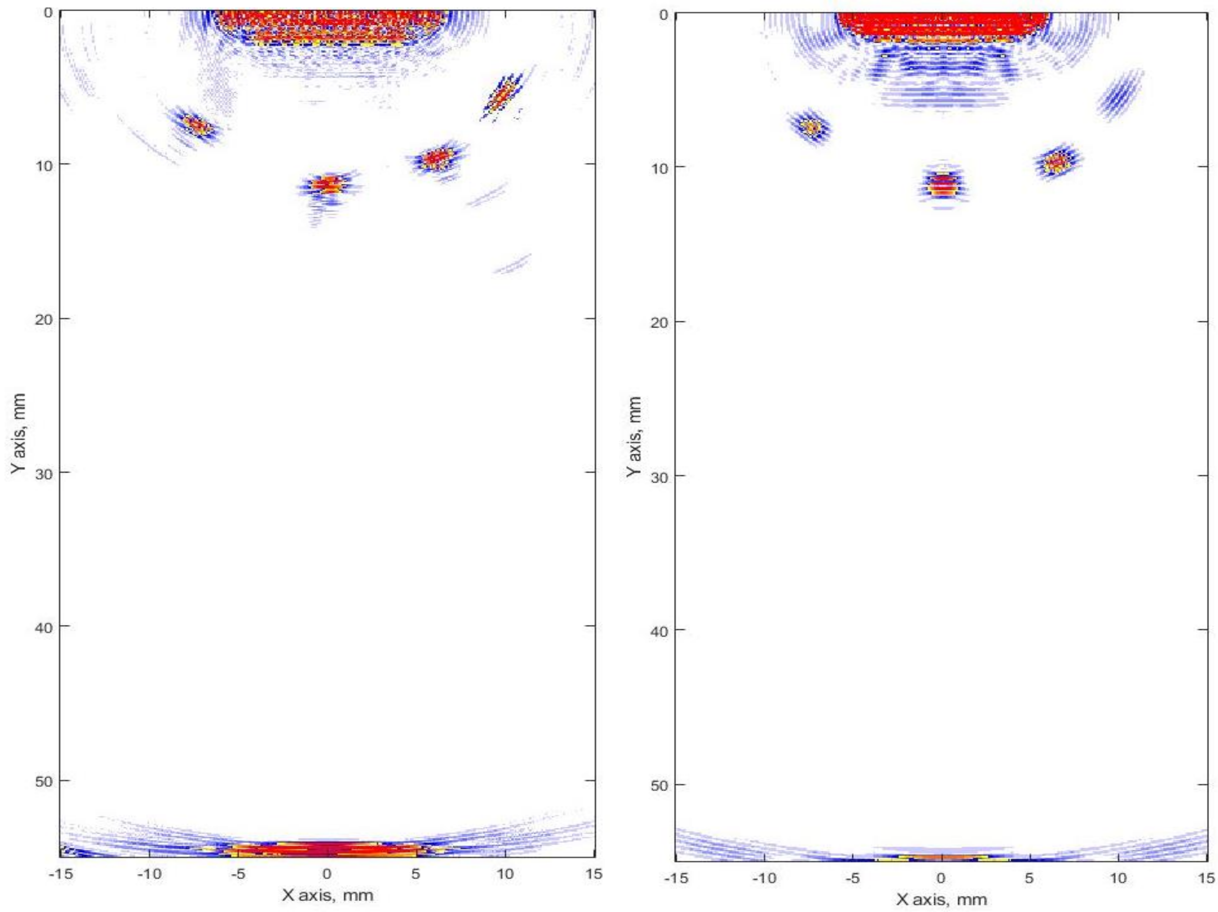


Figure 3.11 – Left: Experimental result; Right: Image: Simulation result

It can be seen that the Array Performance Indicator esteem is fundamentally diminished when utilizing focusing, in execution total focusing method. Note that the most extreme execution for the total focusing method happens when the probe is situated just past or in the near field length of the aperture. This is known as natural focus point of a plane transducer and is the point at which the signal is generally clear. It can likely to be seen that Total focusing method is noteworthy.

Table 3.5 – The array performance indicators for each flaw obtained via simulation and experiment is provided with difference.

Flaw	Experimental API	Simulation API	Difference, %
A	1,114	1,106	0,722
B	1,032	1,013	1,911
C	1,354	1,365	-0,806
D	1,834	1,881	-2,531

This work has presented total focusing methods for ultrasonic imaging with phased array by two approaches. First is the experimental Array Performance Indicator and second is the simulation Array Performance Indicator with differential flaw are presented in the above table from the data acquired with a steel block containing side drilled holes. Results obtained through simulation and experiment are much closer and there not much difference between them. So we can accept that the results obtained through simulation is acceptable.

3.4 Conclusion

This work has exhibited various post-processing algorithm for use in non-destructive testing of ultrasonic imaging with phased array which includes three methodologies. They are Plane wave imaging, Total focusing method and Electronic focusing. The analytical comparison of techniques for ultrasonic imaging with phased arrays was done by two methods one is by Computer simulation and other was done by analysis on literature reviews. The execution of every algorithm was contrasted by evaluating its capacity with image. Tentatively this approach was carried out from 0mm to 10mm. Simulation was performed using various techniques through CIVA application. Results were obtained, as we find that Plane wave imaging is not effective with the increase of the angle between the flaw and central line of the probe which will result in poor quality of imaging. Electronic Focusing and Total Focusing Method doesn’t have such problem. But for Electronic Focusing the physical focusing of the point is necessary. In Electronic Focusing the results are obtained only in the point of focusing. In this case, effect of deviation of flaw and position of flaw should be studied. For this purpose we do additional simulation where we can increase the distance and position of the flaw and focusing. It has been demonstrated that the best execution of the exhibit was accomplished utilizing a Total Focusing Method in which the beam is engaged at each point in the objective region. The results obtained through is a proof that Total Focusing Method is good compared to other methods. An experiment was carried out to find flaws in the specimen through Total Focusing Method, we use an ultrasonic transducer to scan the specimen through various position according to the flaws. From information procured with a steel block containing side drilled holes, we have demonstrated the Total focusing method through an experiment. Data was obtained which is then compiled and processed. The output was received after the processing of data sampling for each step, once the data is compiled. We plot the graph and analyse it to find the flaws in the specimen. Comparing the results obtained by Array Performance Indicator through experiment and simulation there is not much deviation for values. Taking in account of Total focusing method Table3.4 describes about the experimental Array Performance Indicator and simulation Array Performance Indicator along with the difference. The Total Focusing Method is productive for near field imaging and far field imaging where other two procedures used to have a dead zone or not clear imaging. In addition, the Total focusing method has a more computation time contrasted with plane wave imaging and electronic focusing. This approach has some boundless plan suggestions for future NDE array systems. Currently, the environment for nuclear power is undergoing a major change and the ensuring of plant safety and reliability is becoming increasingly important as expectations for nuclear power generation grow. Phased array plays a vital by developing more advanced inspection technologies in non-destructive testing technologies. According to literature reviews we have defined the techniques which are considered for ultrasonic imaging with phased array. Comparison of techniques was done by literature review. Total Focusing Method enables inspection to be performed in more realistic and reliable ways in nuclear industry. It is concluded that total focusing method is the most promising method according to the results obtained.

4 Financial management, resource efficiency and resource conservation

4.1 Introduction to SWOT

The projections made into scientific researches are not only determined by the scale of the discovery and resource-efficient product, but also it can be seen as a commercial value of development. Evaluation of the commercial potential of development is a prerequisite in the search for sources of funding for scientific research and commercialization of its results. This is of great significance as developers needs represent the state and prospects of ongoing research. The commercial attractiveness of scientific research is determined not only by exceeding technical parameters over previous developments, but also how quickly the developer will be able to find answers to such questions as whether the product will be in demand by the market, how much will it cost that will be reasonable to the customers, what is the budget of the scientific project, etc.

The section of financial management in this dissertation consist of two main aspect. The first aspect discusses cost of various methods of ultrasonic phased array testing used in the nuclear industry. Its resource efficiency and consolidated energy investment. The second includes a budgetary report of the scientific project. The cost evaluation was performed for competitiveness of various techniques based on SWOT Analysis.

SWOT analysis (alternatively SWOT matrix) is an acronym for strengths, weaknesses, opportunities, and threats and is a structured planning method that evaluates those four elements of an organization, project or business venture. A SWOT analysis can be carried out for a company, product, place, industry, or person. It involves specifying the objective of the business venture or project and identifying the internal and external factors that are favourable and unfavourable to achieve that objective. Some authors credit SWOT to Albert Humphrey, who led a convention at the Stanford Research Institute (now SRI International) in the 1960s and 1970s using data from Fortune 500 companies. However, Humphrey himself did not claim the creation of SWOT, and the origins remain obscure. The degree to which the internal environment of the firm matches with the external environment is expressed by the concept of strategic fit.

4.2 Definition of Financial management by scholars.

Scholars in the field of financial management have different definitions for the term as stated below;

S.C. Kuchal says "Financial Management deals with procurement of funds and their effective utilization in the business" [38].

Howard and Upton: Financial management "as an application of general managerial principles to the area of financial decision-making [39].

Weston and Brigham: Financial management "is an area of financial decision-making, harmonizing individual motives and enterprise goals" [40].

Joshep and Massie: Financial management "is the operational activity of a business that is responsible for obtaining and effectively utilizing the funds necessary for efficient operations [41].

Therefore, considering the definition made by these scholars we can conclude that:

Financial Management is simply concerned with the effective funds management in the nuclear industry. Industrial Resource efficiency is often defined in supply chain terms, highlighting a firm's material, natural resource and energy efficiencies, and the generation and impact of waste. In some cases, only the resource efficiency of non-energy carrying materials is considered. In this case, the term 'material productivity' is used instead of the resource efficiency.

4.3 Competitiveness of Ultrasonic testing with SWOT Analysis

The SWOT analysis is a compact method to illustrate the results obtained by this study in a strategic way. The Strengths and Weaknesses Ultrasonic testing in nuclear industry are reported to internal factors evaluation. The Opportunities and the threats are reported from external factors evaluation. Some collected strengths of considerable importance for the competitiveness and profitability of an investment. These opportunities are very relevant and although they cannot be quantified and valued, provides a strategic advantage that adds competitiveness to a possible production and usage of ultrasonic non-destructive testing.

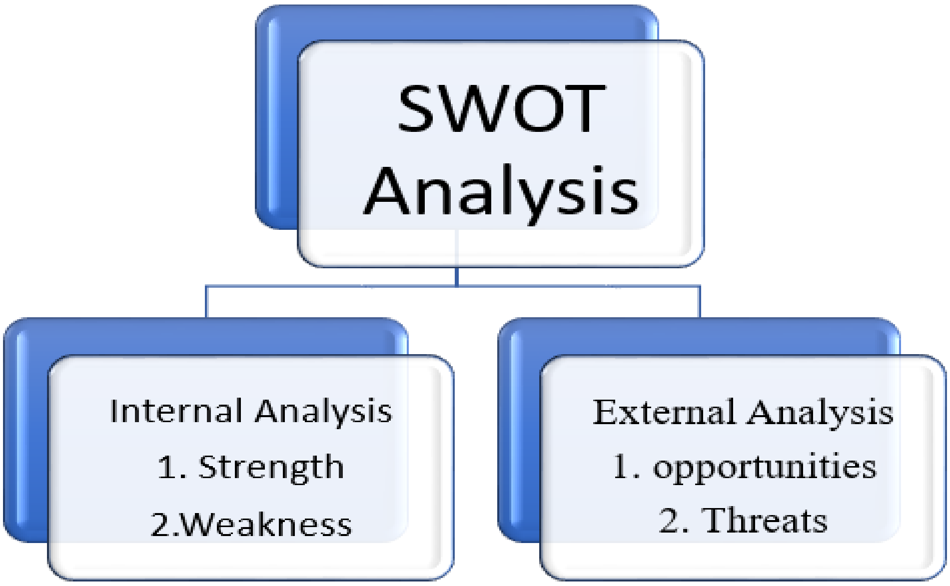


Figure 4.1 – SWOT analysis

Strengths: "Strength" are understood here as internal factor which positively impact the relative competitiveness of nuclear industry in the future. It characteristics of the business or project that give it an advantage over others. The following list of opportunities has been identified:

– The existence of ultrasonic testing adds to producing high efficiency of nuclear reactor designs;

– They provide high operation reliability to the pipeline and the turbine unit as a whole;

– The testing of ultrasonic imaging are quite simple and viable.

– Social benefits of nuclear power include direct employment and positive impacts of stable and predictable cost of electricity on the economy.

Weakness: “Weakness” are understood here as internal factor which positively impact the relative competitiveness of nuclear industry in the future. The following list of opportunities has been identified. It characteristics of the business that place the business or project at a disadvantage relative to others;

– The louvre separator more weight to the steam generator because it is metal-intensiveness. This will add more to the cost of production of these steam generators.

– It comes along with additional cost in terms of maintenance and cleaning. More money will be spent to keep the steam generator properly working

– Its complicated removal of separated water in order not to interfere with the evaporation surface because it can lead to reducing steam volume.

Opportunities: “Opportunities” are understood here as external factor which positively impact the relative competitiveness of nuclear in the future. The elements in the environment that the business or project could exploit to its advantage.

Threats: “Threat” here are understood as the external factors that could threaten or negatively impact the relative competitiveness of nuclear in the future. elements in the environment that could cause trouble for the business or project. The following are list of threats that has been identified:

– Risk of accident during plants’ operation, and corresponding risk perception following bad accident management;

– The global energy competitive markets design in the near future;

– Uncertainties in the construction cost i.e. increase in construction.

Identification of SWOTs is important because they can inform later steps in planning to achieve the objective. First, decision-makers should consider whether the objective is attainable, given the SWOTs. If the objective is not attainable, they must select a different objective and repeat the process.

Users of SWOT analysis must ask and answer questions that generate meaningful information for each category (strengths, weaknesses, opportunities, and threats) to make the analysis useful and find their competitive advantage. SWOT analysis aims to identify the key internal and external factors seen as important to achieving an objective. SWOT analysis groups key pieces of information into two main categories:

Internal factors: The strengths and weaknesses internal to the organization.

External factors: The opportunities and threats presented by the environment external to the organization.

Analysis may view the internal factors as strengths or as weaknesses depending upon their effect on the organization's objectives. What may represent strengths with respect to one objective may be weaknesses (distractions, competition) for another objective. The factors may include all of the 4Ps as well as personnel, finance, manufacturing capabilities, and so on.

The external factors may include macroeconomic matters, technological change, legislation, and socio-cultural changes, as well as changes in the marketplace or in competitive position. The results are often presented in the form of a matrix.

SWOT analysis is just one method of categorization and has its own weaknesses. For example, it may tend to persuade its users to compile lists rather than to think about actual important factors in achieving objectives. It also presents the resulting lists uncritically and without clear prioritization so that, for example, weak opportunities may appear to balance strong threats.

It is prudent not to eliminate any candidate SWOT entry too quickly. The importance of individual SWOTs will be revealed by the value of the strategies they generate. A SWOT item that produces valuable strategies is important. A SWOT item that generates no strategies is not important.

SWOT: Strength, Weakness, Opportunity, Threat. A SWOT analysis guides you to identify your organization’s strengths and weaknesses (S-W), as well as broader opportunities and threats (O-T). Developing a fuller awareness of the situation helps with both strategic planning and decision-making.

The SWOT method was originally developed for business and industry, but it is equally useful in the work of community health and development, education, and even for personal growth.

SWOT is not the only assessment technique you can use. Compare it with other assessment tools in the Community Tool Box to determine if this is the right approach for your situation. The strengths of this method are its simplicity and application to a variety of levels of operation.

Strengths	Weaknesses
• Potential series production of reactors (« off-the-shelf product ») • Reducition of construction period of low-power units (reduction of civil works) • More accessible financing for reactors (lower global construction cost than high-power stations)	• Ill-suited certification process of new reactors for spatial multiplication of units • Necessary adaptation of international safety controls (e.g.: prescriptive character of recommendations based on peer reviews)
Opportunities	**Threats**
• Emergence of new markets (electro-intensive industry, isolated sites, replacement of low-power production stations, etc.) • Aftereffects on the whole nuclear industry and especially on the downstream sector (dismantling and waste treatment)	• Nuclear proliferation with multiplication of units • Acceptability by populations and politics (difficulty to perceive nuclear energy as an energy of the future)

Figure 4.2 – SWOT analysis schematic representation.

Listing Your Internal Factors: Strengths and Weaknesses (S, W):

– Human resources include staff, volunteers, board members, target population;

– Physical resources include your location, building, equipment;

– Financial part include grants, funding agencies, other sources of income;

– Activities and processes include programs you run, systems you employee ;

– Past experiences include building blocks for learning and success, your reputation in the community.

Don't be too modest when listing your strengths. If you're having difficulty naming them, start by simply listing your characteristics (e.g.., we're small, we're connected to the neighbourhood). Some of these will probably be strengths.

Although the strengths and weakness of your organization are your internal qualities, don't overlook the perspective of people outside your group. Identify strengths and weaknesses from both your own point of view and that of others, including those you serve or deal with.

How do you get information about how outsiders perceive your strengths and weaknesses? You may know already if you've listened to those you serve. If not, this might be the time to gather that type of information. See related sections for ideas on conducting focus groups user surveys and listening sessions.

Listing External Factors: Opportunities and Threats (O, T)

– Cast a wide net for the external part of the assessment;

– No organization, group, program or neighbourhood is immune to outside events and forces;

– Consider your connectedness, for better and worse, as you compile this part of your SWOT list.

Forces and facts that your group does not control include:

– Future trends in your field or the culture;

– The economy - local, national, or international;

– Funding sources - foundations, donors, legislatures;

– Demographics - changes in the age, race, gender, culture of those you serve or in your area;

– The physical environment (Is your building in a growing part of town? Is the bus company cutting routes?);

– Legislation (Do new federal requirements make your job harder...or easier?);

– Local, national or international events;

The most common users of a SWOT analysis are team members and project managers who are responsible for decision-making and strategic planning.

An individual or small group can develop a SWOT analysis, but it will be more effective if you take advantage of many stakeholders. Each person or group offers a different perspective on the strengths and weaknesses of your program and has different experiences of both.

Likewise, one staff member, or volunteer or stakeholder may have information about an opportunity or threat that is essential to understanding your position and determining your future.

4.4 Project plan

As part of the planning of the research project, a calendar schedule is constructed using the Gantt chart. In this case, the work on the topic is represented by long stretches. The line chart is presented in Table 4.1, 4.2, 4.3 and 4.4.

Project stakeholders and Participants include:

– Research Institute (Performer: Heads, Supervisors and Students)

– Business company dealing with radiation monitoring and Nuclear fuel use activities (Head of Company, Engineers and Consultants)

– Educational Institutions (Head, Engineers and Consultants)

Table 4.1: Morphological matrix for research implementation alternatives

Characteristics	Alternatives		
	1	2	3
Entity	University	Research Institute	Business Company
Executives	Supervisor	Head of institute	Head of Company
Materials	Free	Bought	Bought
Equipment	Free	Bought	Rented
Software	General	Special	Special
Software access	Free	Free	Free

Facilities	Classroom	Lab	Office
Facilities access	Free	Bought	Rented

Table 4.2: Alternative 1: University

Main stages	No. of work	Work Content	Executive
Development of technical specifications	1	Selection of research topics	Supervisor
Selection of Research direction	2	Study of scientific literatures	Engineer
	3	practice	Engineer
	4	Searching for material and studying in library	Engineer
	5	Data processing	Engineer
Theoretical and experimental study	6	Comparison of experimental results with theoretical studies	Supervisor Engineer
	7	Split the general topic into detailed sub topic	Supervisor Engineer
	8	Self-studying	
	9	Writing papers	
	10	Check the correction of the paper	Supervisor Engineer
Synthesis and evaluation of results		Evaluation of the effectiveness of the results. Team working	
Development of		Translate foreign materials	

technical documentation and design		Attend in conference	

Table 4.3: Alternative 2: Research Institute

Main stages	No. of work	Work Content	Executive
Development of technical specifications	1	Development of terms of reference for approval	Head of department
	2	Drafting and approval of technical specifications	Head of department
Selection of Research direction	3	Choice of direction of research and the way to solve the problem	Engineer
Theoretical and experimental study	4	Collection of data and study of scientific and technical literature	Engineer
	7	Development and modeling of the source code	IT Specialist/Programmer
	8	Simulation the source code and establishment of results	IT Specialist/Programmer
	9	Analysis and processing of the results	Engineer & IT Specialist/Programmer
Synthesis and evaluation of results	10	Evaluation of results obtained and check for errors	Engineer & Supervisor
Conducting R & D			
Development of technical	12	Development an explanatory note to be presented to head of department	Engineer

documentation and design	13	Presentation of result 1	Head of department
	14	Present the result 2	Board Members

Table 4.4: Alternative 3: Business Company

Main stages	No. of work	Work Content	Executive
Development of technical specifications	1	Development of terms of reference for approval	Consultant/Head of Company
	2	Drafting and approval of technical specifications	Consultant/Project Manager
Selection of Research direction	3	Choice of direction of research and the way to solve the problem	Head of Company & Project Manager
Theoretical and experimental study	4	Collection of data	Consultant
	5	Simulation the source code and establishment of results	Consultant
	6	Analysis and processing of the results	Consultant & Project manager
Synthesis and evaluation of results	7	Evaluation of results obtained and check for errors	Consultant & Project manager
Conducting R & D			

Development of technical documentation and design	8	Development of explanatory note	Consultant
	9	Review of the presented report from the Consultant	Head of Company & Project Engineer
	10	Present the result 2	Consultant

4.5 Research budget

When planning the research budget, a complete and reliable reflection of all types of costs associated with its implementation should be ensured. In the process of budgeting, the following cost groupings are used for the items:

– material costs;

– expenses for special equipment for scientific (experimental) works;

– the main salary of the performers of the topic;

– additional wages of the topic's executors;

– deductions to off-budget funds (insurance contributions);

– costs of scientific and production trips;

– counteragent costs;

– overhead.

Calculation of material costs is carried out according to the following formula:

$$C_m = (1 + k_{tr}) * \sum_{i=1}^{m} P_i * N_i \quad (4.1)$$

Where, m – Number of types of material resources consumed in carrying out scientific research;

N_i – The number of physical resources i^{th} species, planned to be used in carrying out scientific research (pieces, kg, m, mon.) and so

P_i – Acquisition unit price i^{th} species consumable material resources (rubles / pc, rub / kg, rub / m, rub / m etc.);

k_{tr} – Co-efficient taking into account transportation and procurement costs.

The values of prices for material resources can be set according to data posted on the respective websites in the Internet companies-manufacturers (suppliers or organizations).

The material costs required for this development are recorded in Table 4.5. The cost of electricity is calculated by the formula:

$$C = T \cdot P \cdot Fob = 2{,}05 \cdot 3{,}6 \cdot 26 + 2{,}05 \cdot 0{,}5 \cdot 400 = 601\text{,rubles}$$

Where, T – Tariff for industrial electricity (2.05 rubles per 1 kW · h);

P – Capacity of equipment, kW;

Fob – Time of use of equipment, h.

The cost of electricity amounted to 601 rubles.

Table 4.5: Material costs

Name	Unit	Quantity			Price per unit, Rub.			Costs of materials (W_m)rub.		
		Alternatives								
		1	2	3	1	2	3	1	2	3
Electricity	kW/hr	293.6	293.6	293.6	2.05	2.05	2.05	601	601	601
Ultrasonic probe		200	200	200	1	1	1	200	200	200
Electronic module		200	500	500	1.5	4	4	300	2000	2000
Computer		1	1	1	150	150	150	150	150	150
Software		-	-	-	-	-	-	-	-	-
Internet	Month	4	3	3	350	1000	1500	1400	3000	4500
Total for materials								2158.8	5951	7451
Transportation and procuring expenses								0	0	0
Total C_m								2158	5951	7451

Calculation of costs for special equipment for scientific (experimental): This article includes all the costs associated with the acquisition of special equipment necessary to carry out work on a particular topic. The cost of depreciation of equipment is calculated by the formula:

$$C_{amount} = \frac{C_r}{T} \quad (4.2)$$

Where, C_r – cost of equipment (rubles);

T – service life (days).

C_{amount} = (3000000/3650) = 821.9 rubles / day.

The equipment was used for 12 days, so the equipment costs:

Alternative 1:

$$C_{amount\ (total)} = 821.9 \cdot 12 = 9863 \text{ rubles}$$

Alternative 2:

$$C_{amount\ (total)} = 821.9 \cdot 12 = 9863 \text{ rubles}$$

Alternative 3:

$$C_{amount\ (total)} = 821.9 \cdot 12 = 9863 \text{ rubles}$$

The cost of electricity is calculated by the formula:

$$C_{elect} = T_f * C_a * E_t \quad (4.3)$$

Where, C_{elect} – Tariff for Industrial Use (2,1 rub/kWh);

T_f – Capacity of equipment;

E_t – Equipment usage time.

At performance of work the stationary computer with average capacity 500 W (0.5 kW). Assuming that all the work was done on it, then all the unit was spent:

Alternative 1: Energy = 90 * 8* 0,5 = 360 kWh

Alternative 2: Energy = 60 * 8* 0,5 = 240 kWh

Alternative 3: Energy = 45 * 8* 0,5 = 180 kWh

(90, 60 and 45 calendar days, eight-hour working day)

Alternative 1: Energy Cost = 360 * 2,1 = 756 rub

Alternative 2: Energy Cost = 240 * 2,1 = 504 rub

Alternative 3: Energy Cost = 180 * 2,1 = 378 rub

The cost of heating, determined by the formula:

$$C_{heat} = (A * T * V) * C \quad (4.4)$$

Where, A – amount of heat per 1 m3 of room ($12{,}57 \cdot 10^{-5}$ Gcal)

T – duration of the heating season

V – volume of the heated room (4 * 4 * 3 m^3)

C – cost for 1 Gcal of heat (1 021,07 rub)

This cost is taken into account in Alternative 1 only:

$$C_{heat} = 12{,}57 * 10^{-5} * 81 * 48 * 1\,021{,}07 = 499{,}02 \text{ rub}$$

The cost of lighting is calculated as follows:

$$C_{lighting} = 15 * A * h * M * \frac{C}{1000} \quad (4.5)$$

Where, A – Floor Area

H – Number of hours of artificial lighting per day (7hours)

W – Number of working days (120 days)

C – Cost of 1 kilojoule of electricity

$$C_{lighting} = 15 * 7 * 16 * 120 * 2{,}1 / 1000 = 423{,}36 \text{ rub}$$

Also the cost of lighting is taken into consideration in alternative 1 only. The main salary of the performers of the topic.

The main salary of the performers of the topic is given by the formula:

$$S_t = S_b + S_{ad} \quad (4.6)$$

Where, S_b – basic salary;

S_{ad} – additional salary.

Basic salary can be calculated, based on hourly labor rates:

$$S_b = S_h * T_s \quad (4.7)$$

Where, S_h – basic salary of one employee per hour, rub/hour;

T_s – the duration of work performed by a scientific and technical worker, rab.dn.

The average daily wage is calculated by the formula

$$S_h = (S_M \cdot M)/F_d \quad (4.8)$$

Sl. No.	Executives	Work, person-days.			Salaries per one person-days, ths. Rub.			Total salaries at the rate (salary), ths. Rub.		
		Alternatives								
		1	2	3	1	2	3	1	2	3
1	Supervisor	15	-	-	350	-	-	31500	-	-
2	Research Director	-	10	5	-	500	550	-	20000	11000
3	Engineer	-	30	45	-	300	300	-	72000	108000
4	Specialist/Consultant	-	30	45	-	350	350	-	84000	126000
5	Student	90	-	-	50	-	-	36000	-	-
Total								67500	176000	245000

Where, S_M – monthly salary of the employee, ruble;

M – number of months of work without leave during the year; with a vacation of 24 workdays, day M = 11.2 months, 5-day week; with a vacation of 48 people. days, M = 10.4 months, 6-day week;

F_d – the actual annual fund of working time of scientific and technical personnel, lab. days (Table 4.6).

Table 4.6 - Calculation of basic salary

Working hours breakdown for the scientific work:

– Supervisor: 6 hours

– Research Director: 4hours

– Engineer: 8 hours

– Specialist:8 hours

– Student: 0

Table 4.7 - Working time balance

Indicators of working hours	Supervisor	Student
Calendar number of days	365	365
Number of non-working days:		

- weekend;	52	104
- holidays	14	14
Loss of working time:		
- vacation;	48	24
- absences due to illness	7	-
The actual annual fund of working hours	244	223

During the pre-diploma practice the student receives a scholarship equal to 2400 rubles per month. The average daily stipend (payment) is:

$$S_h = (2400 \cdot 11.2)/223 = 120.538 \text{ rub/day}$$

The basic earnings of the student during the pre-diploma practice is:

$$S_b = 120.538 \cdot 45 = 5424.21 \text{ rub}$$

The basic salary of the supervisor is calculated on the basis of the sectoral labor payment. The sectoral wage system in TPU assumes the following composition of wages:

– Salary determined by the enterprise. In TPU, salaries are distributed in accordance with the positions held, for example, the assistant, art. lecturer, associate professor, professor.

– Incentive payments - are established by the head of units for effective work, performance of additional duties, etc.

– Other payments: district coefficient.

The head of this research work is an employee with the position of a senior teacher. The salary of the senior teacher is 16752 rubles.

The wage increments are 10,000 rubles (surcharges of the academic council), and the district coefficient for Tomsk is 1.3.

The basic salary of the supervisor of studies:

$$S_b = 16752 \cdot 1.3 + 10000 = 31777.6 \text{ rub/month}$$

Average daily salary of the supervisor:

$S_h = (31777.6 \cdot 10.4)/244$ =1354.45 rub/day

Additional salary of the performers of the topic: The costs of additional wages of the performers of the topic take into account the amount of additional payments provided for by the Labor Code of the Russian Federation for deviation from normal working conditions, as well as payments related to the provision of guarantees and compensations.

Additional wages are calculated based on 10-15% of the basic wages of employees directly involved in the implementation of the topic:

$$S_{ad} = k_{ad} * S_b \quad (4.9)$$

Where, k_{ad} – factor of additional salary (taken at the design stage at 0.12 - 0.15).

We take the coefficient of additional wages equal to 0.15 for the supervisor and 0.1 for the student.

Contributions to social funds (insurance contributions):The amount of deductions to off-budget funds is 27.1% of the total cost of labor for workers directly engaged in the performance of research. In Russian Federation, employees pay insurance payments for state social insurance fund (SIF), the Pension Fund (PF) and medical insurance fund (MIF). Employers on behalf of the employees make these payments.

Contributions to these funds determined based on the following formula:

$$S_f = k_f * (S_b + S_{ad}) \quad (4.10)$$

Where, k_f – coefficient for payments to funds (SIF, PF, MIF).

In 2018 the size of insurance payments was set at the level of 30%. Yet for institutions engaged in educational and scientific activity the reduced rate of 27.1% is used.

$$S_f = 0.271 \cdot (31777.6 + 4766.64) = 9903.48 \text{ rub}$$

Table 4.8 - Contributions to social funds

Executive	Basic salary, rubles.			Additional salary, rubles.		
	Alt.1	Alt.2	Alt.3	Alt.1	Alt.2	Alt.3
Supervisor	31777.6	-	-	4766.64	-	-

Research Director	-	20000	11000	-	2400	1320
Engineer	-	72000	108000	-	8640	12960
Specialist/Consultant	-	84000	126000	-	10080	15120
Student	5424.21	-	-	542.421	-	-
Ratio of contributions to social funds	0,27	0,3	0,3	0,27	0,3	0,3
Total amount of social fund payments						
Alternative 1	42510.871					
Alternative 2	59136					
Alternative 3	78240					

Overheads: This article includes the costs of management and maintenance, which can be attributed directly to a particular topic. In addition, this includes expenses for the maintenance, operation and repair of equipment, production tools and equipment, buildings, structures, etc.

Calculation of overheads is carried out according to the following formula:

$$S_{fo} = k_{fo} * (S_b + S_{ad}) \quad (4.11)$$

Where, k_{fo}– is the overhead rate.

Overhead costs in TPU are 25-35% of the amount of basic and additional wages of employees involved in the implementation of the topic. We take k_{fo} on = 30%.

Overheads are:

$$S_{fo} = 0.3 \cdot (31777.6 + 4766.64) = 10963.3 \text{ rub}$$

Budgeting for the research project budget: The calculated value of the costs of research work is the basis for the formation of the project cost budget, which, when forming an agreement with the customer, is protected by a scientific organization as the lower limit of the cost of developing scientific and technical products.

The definition of the cost budget for a research project for each option is shown in Table 4.9.

Table 4.9 - Calculation of the expenditure budget of the research project

Section	Amount in rubles

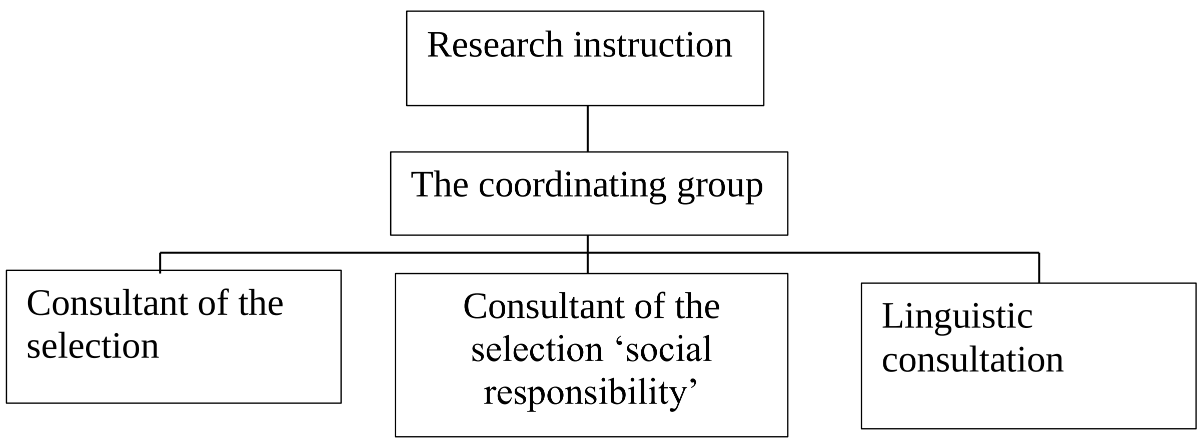
	Alt.1	Alt.2	Alt.3
1. Material Cost	2158.9	9 433,2	11 233,2
2. Equipment Costs	9863	1482	1111,5
3. Electricity Cost	756	504	378
4. Cost of heating	4992	-	364984
5. Lighting cost	423,36	-	-
6. Salaries	67 500	176 000	245 000
7. Costs for the additional salary of the performers of the topic	12 825	21 120	29 400
8. Deductions to off-budget funds	42510.9	59 136	78 240
9. Overheads	10963.3	42 828	58 458
Total Cost	147499	310 503	423 381

4.6 Organizational structure of the project

The organizational structure of the project is a temporary structural formation, created to achieve the set goals and objectives of the project and includes all participants in the process of performing the work at each stage.

This work corresponds to the functional structure of the organization. That is, the organization of the work process is hierarchically structured: each project participant has a direct supervisor, the staff is divided into areas of specialization, each group is led by a competent specialist (functional manager).

The organizational structure of the scientific project is presented in Figure 4.3



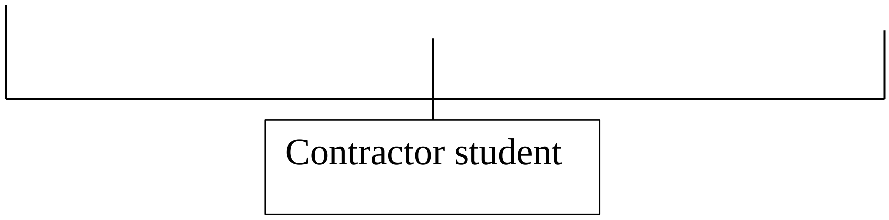


Figure 4.3 - Organizational structure of the scientific project

4.7 Definition of resource saving, financial, budgetary, social and economic effectiveness of the study

The definition of efficiency is based on the calculation of the integral indicator of the effectiveness of scientific research. Its location is associated with the definition of two weighted averages: financial efficiency and resource efficiency.

The integral indicator of the financial effectiveness of scientific research is obtained in the course of estimating the budget of costs of three (or more) versions of the scientific research. For this purpose, the largest integral indicator for the implementation of the technical task is taken as the calculation base (as a denominator), with which the financial values for all execution options are correlated.

Integral financial efficiency indicator development is defined as:

$$E_{fin}^{alt.i} = \frac{TC_i}{TC_{max}} \quad (4.12)$$

Where, $E_{fin}^{alt.i}$ – an integral index of financial efficiency;

TC_i – Total cost of the i^{th} alternative;

TC_{max} – the maximum total cost of research project (including analogs).

The resulting value of the integral financial indicator reflects the cost relationship of each alternative to the most expensive one.

The obtained value of the integral financial indicator of the development reflects the corresponding numerical increase in the development costs budget in times (value greater than one), or the corresponding numerical reduction in the cost of development in times (the value is less than one, but greater than zero).

Since the development has one execution, then:

$$E_{fin}^{alt1} = \frac{TC_1}{TC_{max}} = \frac{147499.5}{423\ 381{,}55} = 0.35;$$

$$E_{fin}^{alt2} = \frac{TC_2}{TC_{max}} = \frac{310\ 503{,}23}{423\ 381{,}55} = 0.7$$

$$E_{fin}^{alt3} = \frac{TC_3}{TC_{max}} = \frac{423\ 381{,}55}{423\ 381{,}55} = 1$$

The integral indicator of resource efficiency of variants of execution of an object of research can be defined as follows:

$$E_{res}^{alt.i} = \sum a_i * b_i \tag{4.13}$$

Where, $E_{res}^{alt.i}$ – an integral indicator resource for ith embodiment of the development;

a_i – weight factor of ith research alternative;

b_i – a score of ith the execution of development options is set by an expert in the chosen scale of assessment;

n – number of parameters comparison.

The integral indicator of resource efficiency is calculated below.

Table 4.10 - Comparative evaluation of the characteristics of project implementation options

	The weighting coefficient of the parameter	Alternatives		
		1	2	3
1. Promotes increased user productivity	0.25	2	3	3
2. Convenience in operation (meets the requirements of consumers)	0.2	2	3	3
3. Noise immunity	0.05	4	3	4

4. Energy Saving	0.2	4	2	4
5. Reliability	0.15	2	4	3
6. Material consumption	0.15	5	4	4
Total	1	2.95	3.1	3.4

$$E_{res}^{alt.1}1 = 2 \cdot 0.25 + 2 \cdot 0.2 + 4 \cdot 0.05 + 4 \cdot 0.2 + 2 \cdot 0.15 + 5 \cdot 0.15 = 2.95;$$

$$E_{res}^{alt.1}2 = 3 \cdot 0.25 + 3 \cdot 0.2 + 3 \cdot 0.05 + 2 \cdot 0.2 + 4 \cdot 0.15 + 4 \cdot 0.15 = 3.1;$$

$$E_{res}^{alt.1}3 = 3 \cdot 0.25 + 3 \cdot 0.2 + 4 \cdot 0.05 + 4 \cdot 0.2 + 3 \cdot 0.15 + 4 \cdot 0.15 = 3.4;$$

Integral total efficiency indicator of alternatives is determined based on the integral resource and financial efficiency by formula:

$$E_{total}^{alt.i} = \frac{E_{res}^{alt.i}}{E_{fin}^{alt.i}} \quad (4.14)$$

Comparative project efficiency indicator: A comparison of the integral index of the effectiveness of project alternatives will determine the comparative project efficiency

Comparative project efficiency indicator is calculated as follows:

$$E_{comp}^{alt.i} = \frac{E_{total}^{alt.i}}{E_{total}^{min}} \quad (4.15)$$

As a result:

$$E_{total}^{alt1} = \frac{E_{res}^{alt}}{E_{fin}^{alt}1} = \frac{2.95}{0.35} = 8.4$$

$$E_{comp}^{alt.2} = \frac{E_{total}^{alt.1}}{E_{fin}^{alt}2} = \frac{3.1}{0.7} = 4.4$$

$$E_{comp}^{alt.3} = \frac{E_{total}^{alt.2}}{E_{fin}^{alt}3} = \frac{3.4}{1} = 3.4$$

Comparison of the integral indicator of the effectiveness of the current project and analogues will allow to determine the comparative efficiency of the project.

Comparative efficiency of the project:

$$E_{comp}^{alt.i} = \frac{E_{total}^{alt.i}}{E_{total}^{min}} \quad (4.16)$$

$$E_{comp}^{alt.1} = \frac{8.4}{3.4} = 2.47$$

$$E_{comp}^{alt.2} = \frac{4.4}{3.4} = 1.29$$

$$E_{comp}^{alt.3} = \frac{3.4}{3.4} = 1$$

The result of calculating the comparative efficiency of the project and the comparative effectiveness of the analysis are presented in Table 4.11.

Table 4.11 - Comparative development efficiency

No. p/p	Indicators	Formula	Alt.1	Alt.2	Alt.3
1	Integral financial efficiency indicator	$E_{fin}^{alt.i}$	0.35	0.7	1
2	Integral resource-efficiency indicator	$E_{res}^{alt.i}$	2.95	3.1	2.4
3	Integral total efficiency indicator	$E_{total}^{alt.3}$	8.4	4.4	3.4
4	Comparative project efficiency indicator	$E_{comp}^{alt.i}$	2.47	1.29	1

4.8 Conclusion

Comparison of the values of integral performance enables to understand and select most effective alternative for solution of the technical problem in the research taking into account financial and resource efficiency. Therefore, Alternative one is proved to be more efficient compared to the other two alternatives.

5 Social responsibility

Nowadays one of the main way to radical improvement of all prophylactic work referred to reduce Total Incidents Rate and occupational morbidity is the widespread implementation of an integrated Occupational Safety and Health management system. That means combining isolated activities into a single system of targeted actions at all levels and stages of the production process.

Occupational safety is a system of legislative, socio-economic, organizational, technological, hygienic and therapeutic and prophylactic measures and tools that ensure the safety, preservation of health and human performance in the work process [42].

Rules for labor protection and safety measures are introduced in order to prevent accidents, ensure safe working conditions for workers and are mandatory for workers, managers, engineers and technicians.

A dangerous factor or industrial hazard is a factor whose impact under certain conditions leads to trauma or other sudden, severe deterioration of health of the worker [42].

A harmful factor or industrial health hazard is a factor, the effect of which on a worker under certain conditions leads to a disease or a decrease in working capacity.

5.1 Analysis of hazardous and harmful factors

The working conditions in the workplace are characterized by the presence of hazardous and harmful factors, which are classified by groups of elements: physical, chemical, biological, psychophysiological. The main elements of the production process that form dangerous and harmful factors are presented in Table 5.1.

Table 5.1 – The main elements of the production process, forming hazardous and harmful factors

Name of the types of work and the parameters of the working process	FACTORS GOST 12.0.003-74 Occupational safety standards system		Normative Documents
	Harmful	Dangerous	
Work with PC	Chemical Toxic		GOST 12.1.007-76 Occupational safety standards system. Harmful substances.
		Electricity	GOST 12.1.038-82 Occupational safety standards system. Electrical safety
	The impact of radiation (HF, UHF, SHF, etc.)		SanPiN 2.2.2 / 2.4.1340-03 Sanitary-epidemiological rules and regulations. "Hygienic requirements for personal computers and organization of work"
	Increased level of ionizing radiation in the work area		Radiation Safety Standards (NRB-99/2009). SP 2.6.1. 2523 -0 9.
		Fire	Fire and explosion safety of industrial installations GOST R12.1.004-85 SSBT

The following factors effect on person working on a computer:

Physical:

– Temperature and humidity;

– Noise;

– Static electricity;

– Electromagnetic field of low purity;

– Illumination;

– Presence of radiation;

– Psychophysiological:

– Psychophysiological dangerous and harmful factors are divided into:

– Physical overload (static, dynamic)

– Mental stress (mental overstrain and monotony of work).

5.2 Organizational arrangements

All personnel are required to know and strictly observe the safety rules. The training of personnel in occupational safety and industrial sanitation consists of introductory briefing and briefing at the workplace by the responsible person.

The qualification commission or by the person responsible for the workplace check the knowledge of safety rules after training at the workplace. After that, commission assign the safety qualification group corresponding to the employee’s knowledge and experience of work and issue a special certificate.

Persons serving electrical installations must not have injuries and illnesses that interfere with manufacturing activity. The state of health is established by medical examination before being employed.

5.3 Technical Activities

The rational layout of the workplace provides for a clear order and permanent placement of objects, means of labor and documentation. Object, what is required to perform the work more often, should be located in the easy reach of the workspace, as shown in Figure 5.1.

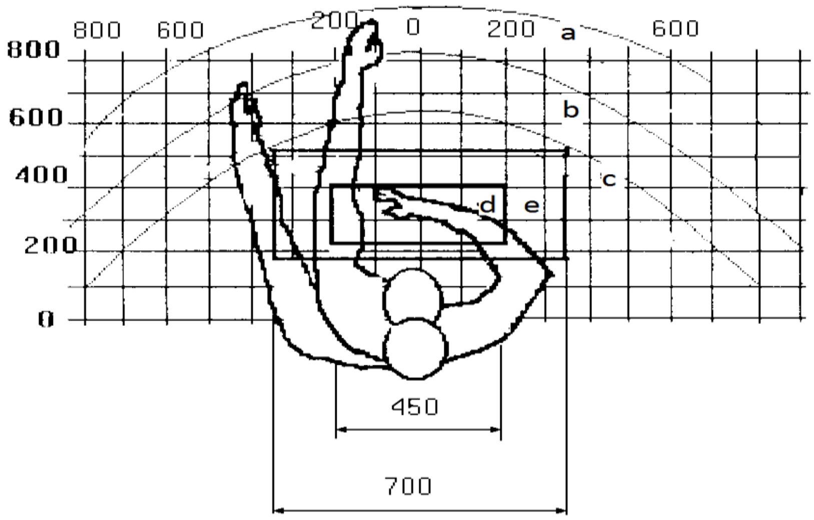


Figure 5.1 – Hand reach zones in the horizontal plane; a - Zone of maximum reach of hands; b - reach zone of fingers with outstretched arm; c - easy reach zone of the palm; d. Optimum space for fine handmade work; e. the optimum space for rough manual work.

Optimal placement of objects of labor and documentation in the reach of hands:

– The display is located in zone a (in the center);

– Keyboard in the area of e / d;

– The system unit is located in zone b (on the left);

– The printer is in zone a (right).

The documentation is placed in the easy reach of the palm - in (left) - literature and documentation necessary for work; In the drawers of the table - literature that is not used constantly. When designing a desk, the following requirements must be taken into account. The height of the working surface of the table should be within 680-800mm. The height of the working surface with the keyboard should be 650 mm. The working table must be at least 700 mm wide and at least 1400 mm long. There should be a legroom of not less than 600 mm in height, a width of at least 500 mm, a depth at the knee level of at least 450 mm and at the level of elongated legs - not less than 650 mm.

The work chair must be liftable and adjustable in height and angle of inclination of the seat and backrest, as well as the distance of the backrest to the front edge of the seat. It is recommended that the height of the seat be above the floor level of 420 to 550 mm. The design of the working chair should ensure: the width and depth of the seat surface is not less than 400 mm; Seat surface with recessed front edge. The monitor should be located at the eye level of the operator at a distance of 500 - 600 mm. According to the norms, the viewing angle in the horizontal plane should be no more than 45º to the normal of the screen. It is better if the viewing angle is 30 °. In addition, it should be possible to select the level of contrast and brightness of the image on the screen.

It should be possible to adjust the screen:

– Height +3 cm;

– Slope from 10 to 20 degrees with respect to the vertical;

– In the left and right directions.

The keyboard should be placed on the surface of the table at a distance of 100 - 300 mm from the edge. The normal position of the keyboard is at the elbow level of the operator with an angle of inclination to the horizontal plane of 15º. It is more convenient to work with keys that have a concave surface, a quadrangular shape with rounded corners. The key design should provide the operator with a click sensation. The color of the keys should contrast with the color of the panel. It is recommended to choose soft, low-contrast floral shades that do not disperse attention (low-saturated shades of cold green or blue colors) in the case of monotonous mental work requiring considerable nervous tension and great concentration. Shades of warm tones are recommended at work, which requires intense mental or physical tension, due to excitation of human activity.

5.4 Safe work conditions

The main parameters characterizing the working conditions are microclimate, noise, vibration, electromagnetic field, radiation, illumination. The air of the working area (microclimate) is determined by the following parameters: temperature, relative humidity, air speed. The optimum and permissible values of the microclimate characteristics are established in accordance with [43] and are given in Table 5.2.

Table 5.2 – Optimal and permissible parameters of the microclimate

Period of the year	Temperature, C^0	Relative humidity,%	Speed of air movement, m / s
Cold and changing of seasons	23-25	40-60	0.1
Warm	23-25	40	0.1

The measures for improving the air environment in the production room include: the correct organization of ventilation and air conditioning, heating of room. Ventilation can be realized naturally and mechanically. In the room, the following volumes of outside air must be delivered:

– At least 30 m^3 per hour per person for the volume of the room up to 20 m^3 per person;

– Natural ventilation is allowed for the volume of the room more than 40 m^3 per person and if there is no emission of harmful substances.

The heating system must provide sufficient, constant and uniform heating of the air. Water heating should be used in rooms with increased requirements for clean air. The parameters of the microclimate in the laboratory regulated by the central heating system, have the following values: humidity 40%, air speed 0.1 m / s, summer temperature 20-25 ° C, in winter 13-15 ° C. Natural ventilation is provided in the laboratory. Air enters and leaves through the cracks, windows, doors. The main disadvantage of such ventilation is that the fresh air enters the room without preliminary cleaning and heating.

Noise and vibration worsen working conditions, have a harmful effect on the human body, namely, the organs of hearing and the whole body through the central nervous system. It result in weakened attention, deteriorated memory, decreased response, and increased number of errors in work. Noise can be generated by operating equipment, air conditioning units, daylight illuminating devices, as well as spread from the outside. When working on a PC, the noise level in the workplace should not exceed 50dB. The screen and system blocks produce electromagnetic radiation. Its main part comes from the system unit and the video cable. According to [43], the intensity of the electromagnetic field at a distance of 50 cm around the screen along the electrical component should be no more than:

– In the frequency range 5 Hz - 2 kHz - 25 V / m;

– In the frequency range 2 kHz - 400 kHz - 2.5 V / m;

– The magnetic flux density should be no more than;

– In the frequency range 5 Hz - 2 kHz - 250nT;

– In the frequency range 2 kHz - 400 kHz - 2 nT.

There are the following ways to protect against EMF:

– Increase the distance from the source (the screen should be at least 50 cm from the user);

– The use of pre-screen filters, special screens and other personal protective equipment.

When working with a computer, the ionizing radiation source is a display. Under the influence of ionizing radiation in the body, there may be a violation of normal blood coagulability, an increase in the fragility of blood vessels, a decrease in immunity, etc. The dose of irradiation at a distance of 20 cm to the display is 50 μrem / hr. According to the norms, the design of the computer should provide the power of the exposure dose of x-rays at any point at a distance of 0.05 m from the screen no more than 100 μR / h. Fatigue of the organs of vision can be associated with both insufficient illumination and excessive illumination, as well as with the wrong direction of light.

5.5 Electrical safety

Depending on the conditions in the room, the risk of electric shock to a person increases or decreases. Do not operate the electronic device in conditions of high humidity (relative air humidity exceeds 75% for a long time), high temperature (more than 35 ° C), the presence of conductive dust, conductive floors and the possibility of simultaneous contact with metal components connected to the ground and the metal casing of electrical equipment. The operator works with electrical devices: a computer (display, system unit, etc.) and peripheral devices. There is a risk of electric shock in the following cases:

– With direct contact with current-carrying parts during computer repair;

– When touched by non-live parts that are under voltage (in case of violation of insulation of current-carrying parts of the computer);

– When touched with the floor, walls that are under voltage;

– Short-circuited in high-voltage units: power supply and display unit.

Measures to ensure the electrical safety of electrical installations:

– Disconnection of voltage from live parts, on which or near to which work will be carried out, and taking measures to ensure the impossibility of applying voltage to the workplace;

– Posting of posters indicating the place of work;

– Electrical grounding of the housings of all installations through a neutral wire;

– Coating of metal surfaces of tools with reliable insulation;

– Inaccessibility of current-carrying parts of equipment (the conclusion in the case of electro porating elements, the conclusion in the body of current-carrying parts) [44].

5.6 Fire and explosive safety

According to [45], depending on the characteristics of the substances used in the production and their quantity, for fire and explosion hazard, the premises are divided into categories A, B, C, D, E.

The room belongs to category B according to the degree of fire and explosion hazard. It is necessary to provide a number of preventive measures.

Possible causes of fire:

– Malfunction of current-carrying parts of installations;

– Work with open electrical equipment;

– Short circuits in the power supply;

– Non-compliance with fire safety regulations;

– Presence of combustible components: documents, doors, tables, cable insulation, etc.

Activities on fire prevention are divided into: organizational, technical, operational and regime.

Organizational measures provide for correct operation of equipment, proper maintenance of buildings and territories, fire instruction for workers and employees, training of production personnel for fire safety rules, issuing instructions, posters, the existence of an evacuation plan. The technical measures include: compliance with fire regulations, norms for the design of buildings, the installation of electrical wires and equipment, heating, ventilation, lighting, the correct placement of equipment. The regime measures include the establishment of rules for the organization of work, and compliance with fire-fighting measures. To prevent fire from short circuits, overloads, etc., the following fire safety rules must be observed:

– Elimination of the formation of a flammable environment (sealing equipment, control of the air, working and emergency ventilation);

– Use in the construction and decoration of buildings of non-combustible or difficultly combustible materials;

– The correct operation of the equipment (proper inclusion of equipment in the electrical supply network, monitoring of heating equipment);

– Correct maintenance of buildings and territories (exclusion of the source of ignition - prevention of spontaneous combustion of substances, restriction of fireworks);

– Training of production personnel in fire safety rules;

– The publication of instructions, posters, the existence of an evacuation plan;

– Compliance with fire regulations, norms in the design of buildings, in the organization of electrical wires and equipment, heating, ventilation, lighting;

– The correct placement of equipment;

– Well-time preventive inspection, repair and testing of equipment.

In the case of an emergency, it is necessary to:

– Inform the management (duty officer);

– Call the Emergency Service or the Ministry of Emergency Situations - tel. 112;

– Take measures to eliminate the accident in accordance with the instructions.

5.7 Conclusion

This dissertation is carried out by step by step systematic analysis of the objectives. To some extent, the current framework of fuel safety criteria remains applicable, being largely unaffected by the “new” or modern design changes; the numeric values of the individual safety criteria may, however, change in accordance with the particular testing techniques and features. Some of these values have already been or are continuously being adjusted.

Assessment of ultrasonic testing safety criteria, the following process is recommended: Continue to further develop best-estimate analysis methods, together with a suitable uncertainty analysis, in all areas of safety analysis. Continue to perform experimental studies for benchmarking of best-estimate codes and extending the verification validation basis for safety criteria and the codes Review, and adjust or change where necessary, safety criteria based on the above codes and test data; define or quantify necessary margin to safety limits.

The process of completion of the project started with doing a systematic SWOT analysis the step by step analysis of strength weakness and opportunities and threats were critically analyzed and after performing these analysis the methodology how to overcome the weakness and threats and how to achieve the objectives.

The payment for achieving the project is evaluated and total number of days required are found out and along with the expenses to carry out the project the overload expenses and social funding is also evaluated.

The final part of the dissertation is social responsibility the project has to be done as per the rules and regulation in-order to achieve that it is necessary to produce a systematic analysis of the safety factors the numerous amount of threat is involved in achieve the goal of the project fire safety electrical safety in order to achieve the success of the project the people who are involved in the project as to trained properly and ultimately safety is achieved. Regarding the fire safety all inflammable materials should be kept away from the fire reachable area and thus fulfilling all these safety measure the project can be executed safely and smoothly thus allowing us to perform all necessary safety precaution during course of the project and regarding the electrical safety proper voltage as to maintained properly and smooth function of the project as to be ensured.

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