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Reduction of Reworks and Rejections in Manufacturing of a Thin walled Aerospace Component

T.Srinivasa Rao[1], Dr.P.Mallesham[2],

(Department Of Mechanical Engineering (Principal& Professor, Department Of Mechanical
M.Tech (Cad/Cam) Sri Indu College Of Engineering & Technology, Jntu Hyd India.

ABSTRACT: *The paper is to review reduction of reworks and rejections in machining of thin-walled components, which has increasingly become a difficulty for manufacturers. Advanced digital analyses have been developed by many researchers to model, predict and reduce errors induced by machining processes. CAD/CAM systems play a vital role in design optimization and process optimization of any component and helpful in reducing the rejections and reworks. The thin wall component taken for this project is a missile shield. The missile shield protects the missile by covering the entire body. This paper also deals with development of manufacturing process plan of missile component (missile shield) using CAM software, which is exclusively CAM software used to generate part program by feeding the geometry of the component and defining the proper tool path and thus transferring the generated part program to the required CNC machine with the help of DNC lines. Keeping in view the above important aspect this paper has been taken up for reducing the rejections to a minimum. In this thesis, the 3D model of missile shield is designed in CAD software and it is imported to ANALYSIS software to perform the dynamic analysis. In this section will discuss about efforts made to produce different process plans in CAM software by changing the work holding systems, tool paths, cutting tools etc. Finally, recommending an optimum process plan for manufacturing of the component to reduce rejection and rework.*

I. INTRODUCTION

About The Component: A missile is a self-propelled guided weapon system. Missiles have four system components: targeting and/or guidance, flight system, engine, and warhead. Missiles come in types adapted for different purposes: surface-to-surface and air-to-surface (ballistic, cruise, anti-ship, anti-tank), surface-to-air (anti-aircraft and anti-ballistic), air-to-air, and anti-satellite missiles. The missile shield protects the missile by covering the entire body. The missile shield design and process planning are studied in detail.

Challenges in Machining Thin-Wall Component: To remain competitive, manufacturer constantly seeks to improve their product quality by producing ‗right first time 'machined component. The tight dimensional tolerance of aerospace component poses a great challenge for the manufacturer especially for machining a component that contains a thin-wall feature. Because of the poor stiffness of thin-wall feature, deformation is more likely to occur in the machining of thin-wall part which resulting a dimensional surface errors [1, 2, 3].

Current Practice in conventional Machining Thin-Wall Component: In current industry practice, the resulting surface errors are usually compensated through one or more of the following techniques: (i) using a repetitive feeding and final ‗float' cut to bring the machined surface within tolerance; (ii) manual calibration to determine ‗tolerable' machining conditions; (iii) a lengthy and expensive trial and error numerical control validation process [4]; and (iv) using a step machining approach, which alternately milling each side of the wall [5]. Distinctly all of these existing techniques on machining thin-wall feature have a tendency to lower productivity and difficulty in ensuring the component accuracy.

To overcome the disadvantages of current industry practice in conventional machining thin-wall component, a finite element method is adopted to model the effect of processing parameter on surface error. They were numerous of reported work claiming the success of employing finite element method using the commercial finite element software for modelling the machining process. Once the surface error is predicted in advanced by finite element method, the surface error compensation strategy can be done. By using the finite element method for predicting the surface error produced in machining can eliminate the shop floor trials which are often very costly, time consuming and labor intensive [6].

The main issue involve in modelling machining process with finite element method is the long computational analysis time. Depending on the complexity of the problem, the computational analysis time can be varied up to day even weeks. This is due to the nature of the FEM calculation which calculates the surface errors for all over the workpiece at every feed step and every angular increment of cutter. This long computational analysis time limit its application for industry practice which must manufacture parts in a few days. Besides that, the limited design flexibility in FEM software requires transfer of model from other CAD software which can cause problems such as loss of data organization, translation inaccuracies, change in number of entities and excessive file size growth. Therefore, there exist an opportunity to improve the analysis efficiency and machining technique for thin-wall component in order to increase the part accuracy and productivity.

II. Literature Review

N. P. Maniar, D. P. Vakharia: -Fixturing contributes significantly to overall manufacturing cost, it is sometimes neglected for the reason of cost reduction. The design and manufacture of fixtures can be time consuming, and it increases the manufacturing cycle time of any product that needs machining and/or assembly. The main reason is that fixtures are designed to tight tolerances, typically 30-50% of the overall work piece tolerance.

J. C. Trappey and C. R. Liu:-Fixture design can be classified as a part of process planning. The task wise description of process planning specifically states that "'fixture design for each work piece set-up" is an integral planning task. However, the automation of fixture design has been overlooked in most research into automated process planning.

1. Fixture configuration - determining the types of fixture elements required, and selecting locating points on the selected elements according to the specified process information.

2. Fixture assembly - constructing and assembling modular fixture components. The orientation of each component on the base plate is determined according to the work piece set-up. Consequently, the assembly sequence of the fixture components is planned for automatic assembly by robot hand.

3. Fixture verification - proving the validity of the fixture configuration with consideration of some operating factors, such as the cutting directions, the acting forces and the machining sequence.

Pollack, 1976:-A Fixture is a work piece locating and holding device used with machine tools, inspection, welding and assembly; it does not control the position of the tool or instrument which is being used

• Elements of the Jig or Fixture must also be present which Support the work and elements, called locators, which Position the work

• Once located and positioned, the work is clamped so that it will not move off the supports or locators.

Burley and Corbett, 1998:-• A Jig is defined as a manufacturing aid that either holds a part or is itself located on the part and is fitted with devices to guide a cutting tool ensuring the correct location of the machining path relative to the part

• A Fixture is defined as a manufacturing aid for holding and locating parts during machining or assembly operations, which do not provide definite guidance for the cutting tools

• Tooling is used as the generic name for jigs and fixtures and also the tools set from the master gauges for calibrating jigs and fixtures

• Hence, Jigless Assembly is assembly without the use of jigs; it requires that parts are manufactured to sufficient accuracy to ensure correct assembly; it is not necessarily fixtureless [or tool less] assembly.

Supporting and Locating Principles:- The main purpose of this section is to describe the "'Fixturing criteria" that ensure the precise locating and rigid supporting of the work piece under various circumstances. There is a total of 12 (2 • 3 x 2) linear and rotational movements along the x-, y- and z-axes, including both positive and negative directions. Usually, supporters and Locators restrict at [east nine movements, with the remaining three possible movements constrained by clamps.

1. Prismatic Parts without an Existing Hole:- According to the ANSI dimensioning and tolerance standard, a "'datum reference frame" of a part can be defined by three perpendicular datum planes. For a prismatic work piece, the datum planes are sequentially related to the defined datum features of the part. The 3-2-1 locating principles can be used to configure the external locating points [4, 6}, which can relate the part to the datum reference frame. First, the three point supporting principle is used to assign three supporting points on the first datum plane; these shall be located as far apart as possible to increase the work piece stability. Five movements will be restricted by following the three point supporting principle. Second, two points are assigned on the second datum plane and can restrict three possible movements. Third, one point has to be assigned on the third datum plane and can restrict one more movement. Totally, nine movements are bound according to the principles. However, the 3-2-1 principles can only be applied for prismatic-work piece Fixturing, and the three perpendicular datum planes and corresponding features must be well defined.

2. General Parts with Existing Hole(s):- For a general part with an existing hole, three supports and a single internal locator may be applied to restrict nine movements at once; this is the most efficient way of locating the work piece. Certain criteria have to be met, for example: The existence of the first datum plane for three-point supporting as described in the previous paragraph The hole used for internal locating should be perpendicular to the first datum plane and open towards the datum plane. The hole in the work piece must be of a suitable diameter to contain an existing internal locator

3. Nonprismatic Parts: - External locating principles have to be applied to restrict the possible movements of the work piece. Several components may be considered for properly supporting and locating the work piece by following the external locating principles. They are: V-blocks for locating or supporting externally cylindrical parts Adjustable supports (e.g. threaded type) and locators for supporting and locating nonplanar or rough surfaces the Fixturing techniques for Nonprismatic parts are often dependent on the work piece shape. Because of the complex nature of work piece geometry, there are no generalised fixture-design principles for Nonprismatic parts, especially

Since multiple choices of design are often available. For those who are interested in details of fixture-design principles, some of the most commonly used Fixturing techniques are described in the book Jig and Fixture Design.

III. COMPUTER AIDED DESIGN (CAD)

Computer-aided design (CAD), also known as computer-aided design and drafting (CADD), is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. Computer-aided drafting describes the process of creating a technical drawing with the use of computer software. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print or machining operations. CAD software uses either vector based graphics to depict the objects of traditional drafting, or may also produce raster graphics showing the overall appearance of designed objects.CAD often involves more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions. CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) space.CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals. The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry.

IV. FINITE ELEMENT ANALYSIS

Finite Element Modelling (FEM) and Finite Element Analysis (FEA) are two most popular mechanical engineering applications offered by existing CAE systems. This is attributed to the fact that the FEM is perhaps the most popular numerical technique for solving engineering problems. The method is general enough to handle any complex shape of geometry (problem domain), any material properties, any boundary conditions and any loading conditions. The generality of the FEM fits the analysis requirements of today's complex engineering systems and designs where closed form solutions are governing equilibrium equations are not available.

Structural analysis comprises the set of physical laws and mathematics required to study and predicts the behavior of structures. Structural analysis incorporates the fields of mechanics and dynamics as well as the many failure theories. From a theoretical perspective the primary goal of structural analysis is the computation of deformations, internal forces, and stresses. In practice, structural analysis can be viewed more abstractly as a method to drive the engineering design process or prove the soundness of a design without a dependence on directly testing it.

3D model of the missile shield was developed in CAD software from the design calculations done. The model was then converted into a parasolid to import into ANALYSIS software. A Finite Element model was developed with solid elements. The elements that are used for idealizing the missile shield were described below. A detailed Finite Element model was built with solid elements to idealize all the components of the missile shield. Modal analysis was carried out to find the natural frequencies. The elements that are used for idealizing the missile shield are solid 92.

Modal analysis is used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It can also serve as a starting point for another, more detailed, dynamic analysis, such as a transient dynamic analysis, a harmonic response analysis, or a Spectrum analysis. The objective of my analysis is to perform the modal analysis of the missile shield and find the natural frequencies

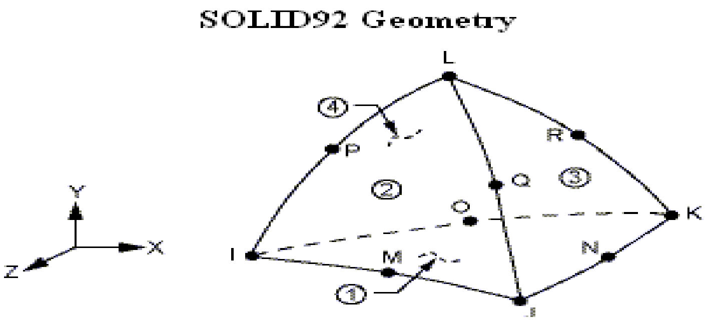
For every natural frequency there is a corresponding vibration mode shape. Most mode shapes can generally be described as being an axial mode, torsional mode, bending mode, or general modes. Like stress analysis models, probably the most challenging part of getting accurate finite element natural frequencies and mode shapes is to get the type and locations of the restraints correct. A crude mesh will give accurate frequency values, but not accurate stress values.All the components of the missile shield are made using Steel, High Strength Alloy ASTM A-514.

Steel, High Strength Alloy ASTM A-514 Mechanical Properties:

Young's modulus = 200Gpa
Yield Strength = 690Mpa
Tensile Strength = 760Mpa
Density = 7850kg/m3
Element Type Used:
Solid 92
Number of Nodes: 10
Number of DOF: 3 (Ux, Uy, Uz)

SOLID92 Element Description

SOLID92 has a quadratic displacement behavior and is well suited to model irregular meshes (such as produced from various CAD/CAM systems). The element is defined by ten nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element also has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities.



The elements that are used for idealizing the missile shield are solid 92.

V. MODAL ANALYSIS OF MISSILE SHIELD

The missile shield was studied to understand the natural frequencies between 0-1000Hz. The Boundary condition used for modal analysis is shown in below figure.

Boundary conditions:

Missile shield is fixed in all Dof at bolting locations.

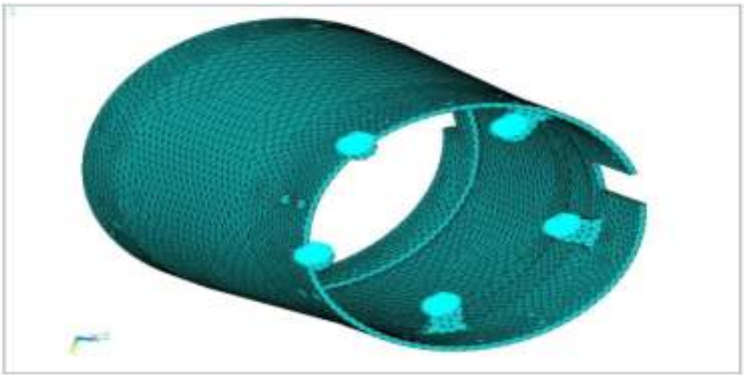


Figure 1: Boundary conditions applied on the missile shield for modal analysis

From the modal analysis, a total of 4 natural frequencies are observed in the frequency range of 0-1000 Hz. The mass participation of each of these 4 frequencies are listed in the below table.

Mode	Frequency	Partic.Factor			Effective Mass		
		X	Y	Z	X	Y	Z
1	501.55	-1e-04	2e-04	-3e-04	1e-08	7e-08	1e-07
2	504.58	-3e-05	1e-04	6e-05	1e-09	1e-08	3e-09
3	926.15	1e-05	1e-03	1e-02	1e-10	3e-06	2e-04
4	941.26	1e-04	1e-02	-1e-03	1e-08	2e-04	3e-06

Table I: Frequencies in the range of 0-1000Hz.

From the modal analysis,

- The total weight of the missile shield is 0.005Tone.
- It is observed that the maximum mass participation of 0.0002Tone in Y-dir for the frequency of 926Hz.
- It is observed that the maximum mass participation of 0.0002Tone in Y-dir for the frequency of 941Hz.
- However RSA analysis has been carried out to check the structure behavior for random vibrations in the frequency range of 0-1000Hz.

Response spectrum analysis (rsa) of missile shield:

A Response spectrum is simply a plot of the peak or steady-state response (displacement, velocity or acceleration) of a series of oscillators of varying natural frequency, that are forced into motion by the same base vibration or shock. The resulting plot can then be used to pick off the response of any linear system, given its natural frequency of oscillation. One such use is in assessing the peak response of buildings to earthquakes.

The missile shield is subjected to a base excitation of 0.2mm in X, Y and Z directions. Response spectrum analysis has been carried out on the missile shield to check the effect of mode combination of the existing natural frequencies. SRSS mode combination is used for the analysis. The boundary conditions used for the RSA are shown in below figures.

Boundary conditions:

- Missile shield is fixed in all Dof at bolting locations.

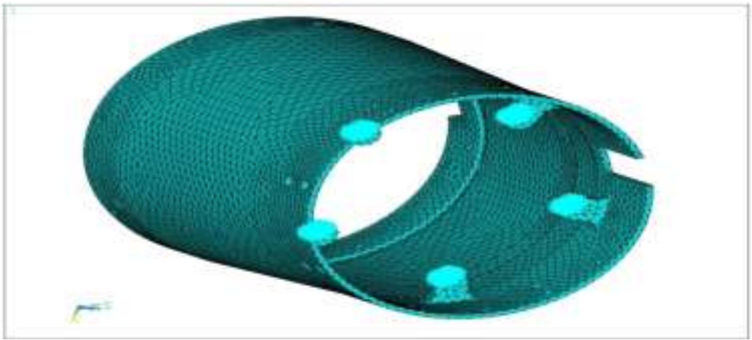


Figure 2: Boundary conditions applied on the missile shield for RSA analysis

the above RSA results observed VonMises stress 2MPa, 279MPa and 402MPa are less than the yield strength of material used for missile shield. The yield strength of the material used for missile shield is 420MPa. According to the VonMises Stress Theory, the VonMises stress of missile shield is less than the yield strength of the material.

VI. COMPUTER AIDED MANUFACTURING

Computer-aided manufacturing (CAM) is the use of computer software to control machine tools and related machinery in the manufacturing of work pieces. This is not the only definition for CAM, but it is the most common; CAM may also refer to the use of a computer to assist in all operations of a manufacturing plant, including planning, management, transportation and storage. Its primary purpose is to create a faster production process and components and tooling with more precise dimensions and material consistency, which in some cases, uses only the required amount of raw material (thus minimizing waste), while simultaneously reducing energy consumption.CAM is a subsequent computer-aided process after computer-aided design (CAD) and sometimes computer-aided engineering (CAE), as the model generated in CAD and verified in CAE can be input into CAM software, which then controls the machine tool.

CAM on missile shield: - Maintaining stable speed missile shield component is manufactured on CNC machine.

Methodology used in manufacturing of missile shield is as mentioned below:
1. Identifying suitable machine.
2. Selecting suitable tools for manufacturing thin walled component.
3. Designing fixture/mandrel to missile shield component for external operations.
4. Listing down the Sequence of operations performed on missile shield component.
5. Generating tool path at specified cutting speed.
6. Generating NC program using CAM software.

Sequence Of Operations Performed On Missile Shield Component
Sequence of operations performed on missile shield in CAM software are listed below

Set up-1
- Facing operation
- OD_Rough_Turn operation
- ID_Rough_Bore operation

Set up-2
- Facing operation
- OD_Rough_Turn operation
- Finally Drilling operation

Cam Operation In Nx-Cam
Basic cam setup
1. In NX the NC machining environment is referred to as the setup.
2. The set up for the machining jobs should be decided by looking at all the environmental information from four viewpoints: Program, Method, Geometry, and Tool.
3. These four viewpoints were designed to mimic the thought process that can be used when planning the NC program.
4. Each viewpoint organizes the information for the operation in a manner relevant to that particular viewpoint.
5. For example there are some standard setups available in NX-CAM are given below.

Setups	What Is In The Initial Setup	What Can Be Created
mill_planar	This contains an MCS, Work piece, Program, and methods for drilling, rough milling, semi-finish milling and finish milling.	Operations, tools, and groups used for drilling and planar milling.
Turning	This contains an MCS, Work piece, Program, and six methods for turning.	Operations, tools, and groups used for turning

Manufacturing Process Of Missile Shield On Cnc Machine.

Raw material is placed on the machine, and degree of freedom is arrested using fixtures. Facing operation is general operation which will be done for any component, after facing internal operations are done on the missile shield

First step: facing operation is done on the raw material
Second step: internal roughing operation done on the component
Third step: the designed mandrel is fixed internally in the missile shield component and external roughing is done
Fourth step: the component is fixed reversely in the fixture and setup_2 operations are done. Outer roughing operation is done.
Fifth step: drilling operation is done on final turning component on milling machine.

Surface finish is not obtained by using non expandable designed mandrel, due to the gap between the mandrel and missile shield component. At high cutting speeds the load of the tool is directly applied on the missile shield component and scratches are formed due to the gap between the missile shield component and mandrel. Hence increase in rejection rate due to bad surface finish. In order to overcome from this rejection rate expandable mandrel is designed for missile shield.

VII. REDUCTION OF REJECTION RATE AND REWORKS RATE

Reducing rejection rate and reworks rate using 5-why (or) why-why analysis which helps in increasing production rate of industry.

5-why analysis (or) why-why analysis

1. It is a method of questioning that leads to the identification of the root cause(s) of a problem.
2. A why-why is conducted to identify solutions to a problem that address its root cause(s). Rather than taking actions that are merely band-aids, a why-why helps to identify how to really prevent the issue from happening again.

Main Causes of Rejection Rate in industries

1. Operator's negligence at work place and their poor knowledge in manufacturing.
2. Rejection rate also increased due to equipment such as component setup, assigning improper tools, fixture design problems.
3. Another cause of increase in rejection rate is due to procedure of machining like mistakes in sequence of operations (Turning, Milling and Drilling).
4. Another cause is following the norms or rules of the company in impossible conditions of machining the component.

Root Causes of Rejection Rate in manufacturing of Missile shield:

Missile shield is thin walled component it is difficult to manufacture.

1. Rejection rate due to equipment such as component setup, assigning improper tools, fixture design problems.
2. Another cause due to improper design of mandrel.
3. Going for high cutting speed which is not preferred for machining Missile shield component in order to reduce machining time.
4. Another cause of increase in rejection rate is due to procedure of machining like mistakes in sequence of operations (Turning, and Drilling).

Solution obtained to reduce rejection and reworks:

1. To reduce rejection rate the thin walled component is manufactured in a sequence as first internal operations and next by using mandrel support external operations are done.
2. Proper tools are specified which will support for machining thin walled component.
3. Redesign of mandrel is done to reach high surface finish without fail.

VIII RESULTS AND DISCUSSION

By considering 2D inputs 3D model is generated using CAD software.

The missile shield as studied for 2 different cases:

- Modal analysis
- Response Spectrum Analysis (RSA)

Modal Analysis

From the modal analysis results it is observed that only 4 natural frequencies exists in the operating range of 0-1000 Hz.

- The total weight of the missile shield is 0.005Tone.
- It is observed that the maximum mass participation of 0.0002Tone in Y-dir for the frequency of 926Hz.
- It is observed that the maximum mass participation of 0.0002Tone in Y-dir for the frequency of 941Hz.

Rsa Analysis

RSA analysis has been carried out to check the structure behavior for random vibrations in the frequency range of 0-1000Hz.

From the RSA results observed VonMises stress 2MPa, 279MPa and 402MPa are less than the yield strength of material used for missile shield. The yield strength of the material used for missile shield is 420MPa. According to the VonMises Stress Theory, the VonMises stress of missile shield is less than the yield strength of the material.

Cam Results
Results are represented graphically to specify the quality control of missile shield component

Graphical representation of rejection and reworks rate
Below graphs shows the rejection and reworks rate before WHY-WHY analysis and after WHY-WHY analysis.

Results before WHY-WHY analysis

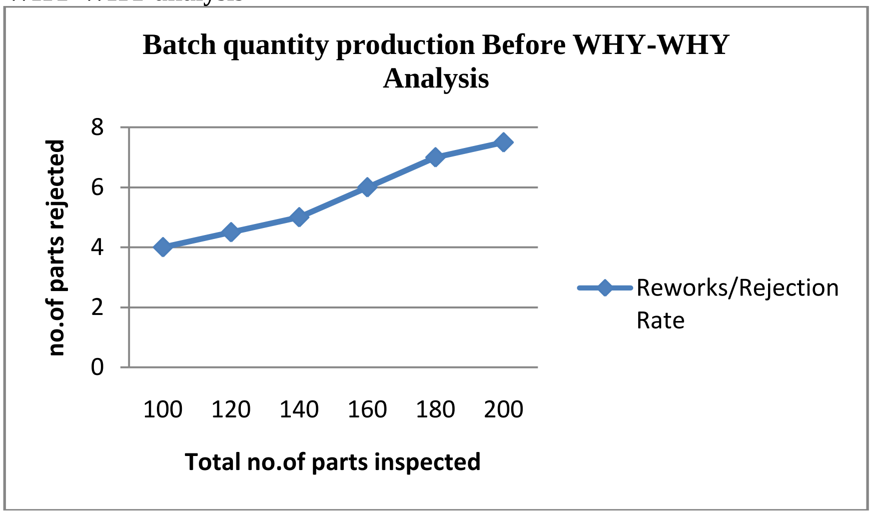


Figure 3: Graph of rejection and reworks rate before WHY-WHY analysis

Results after WHY-WHY Analysis
These four causes for rejection which are mentioned above is rectified by using WHY-WHY Analysis. The following graph indicates rejection rate after WHY-WHY Analysis.

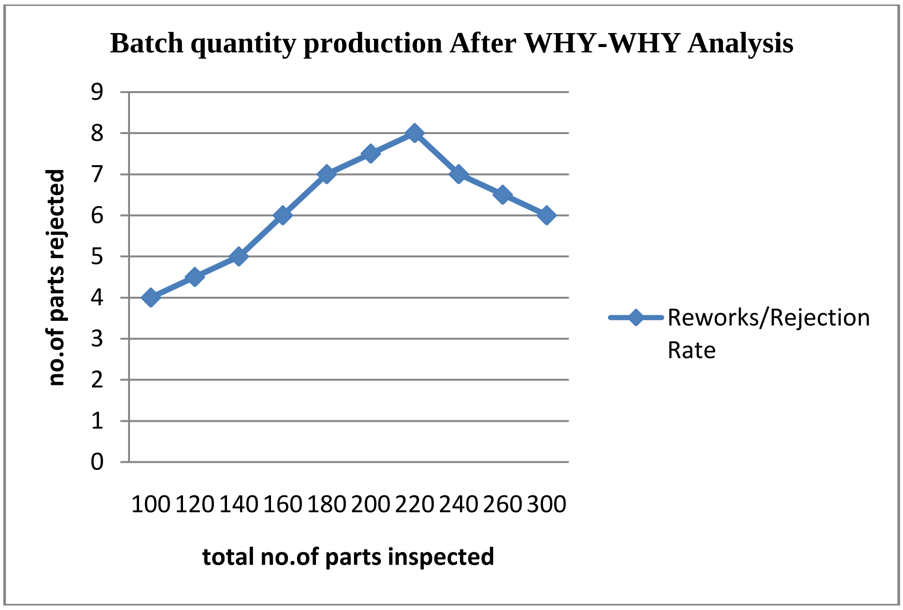


Figure4: Graph of rejection and reworks rate after WHY-WHY analysis

From the above result graphs it is concluded that the reworks and rejection rate is decreased from 9% to 6% after using WHY-WHY Analysis.

IX. CONCLUSION

In this thesis the missile shield has been designed and analyzed for Dynamic behavior and Tool path is generated. From the above analysis it is concluded that the missile shield has stresses and deflections within the design limits of the material used. The deflections and stresses obtained in the spectrum analysis are also under the design limits of the material.

Therefore it concluded that the missile shield is safe under the random loading conditions.

1. Tool path is generated on missile shield using NX_CAM software.
2. The thin walled (missile shield) component is manufactured in a sequence as first internal operations and next by using mandrel support external operations are done to reduce rejection rate.
3. Proper tools are specified which will support for machining thin walled component.
4. By WHY-WHY analysis is done to check rejection and rework rate is reduce or not.
5. Graphical representation of rejection and reworks rate before and after WHY-WHY analysis is shown in results.

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