APPROVAL

"I hereby, declare that I have read thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor Mechanical Engineering (Structure and Material)"

Signature : ....

Name of Supervisor : Prof Madya Dr. Ahmad Rivai

Date : 23/06/2016

FATIGUE ANALYSIS ON CENTRIFUGAL WHEEL COMPONENT OF AUTOMATIC BLASTING MACHINE

AMEER HAFETZ BIN JOHAR

A report submitted
In fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering (Structure & Materials)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

DECLARATION

"I hereby, declare this thesis is the results of my own research except as cited in the references"

Signature	:..
Author's Name	: Ameer Hafetz bin Johar
Date	: 23/06/2016

Dengan nama

Allah Yang Maha Pemurah, Lagi Maha Penyayang

AKNOWLEDGEMENT

In the name of God, the most kind and merciful, I would like to stretch my gratitude firstly to Allah for blessing me with good health, opportunities and the courage to complete my learning journey throughout my 6 years here in Universiti Teknikal Malaysia Melaka. Without his blessing I would not be here as a student nor as a person who is only a small individual that is keen to seek knowledge. Through happiness and pain, ups and downs, I managed to strive myself with my own effort to become who I am today.

Next, to my caring father Mr. Johar bin Juhari and my loving mother Mrs.Olibiah binti Pardi, for all their unwavering support even though all my times were spent being away from the family. I hold your name high throughout my time here, becoming my strength to strive form being good to being great for what I believing in. As nothing can make me feel happier to repay all of your sacrifices in becoming a wise human being.

Finally, I would like to express my profound gratitude to my *Projek Sarjana Muda* advisor, Prof. Madya Dr. Ahmad Rivai, for his time, patience and guidance to not only taught but also coaches throughout my studies. His willingness to express his view, idea and challenge the knowledge of a student really shape my understanding in doing my research under his watchful eyes. It is an honor to do my research under a renown Finite Element Analysis lecturer here in UTeM and my success I dedicated to you.

ABSRACT

An AutoBlast machine or the more renown as the Centrifugal Blasting Machines, is a machine used in surface finish process of metal. Inside the blasting machines is equipped with a rotating wheel housing a sets of blades powered by electrical motor. The heavy rotating wheel is feed with abrasive media called grits that is then being shot out in high velocity propelling the grits on to the surface of any metal test piece. Due to the high rotating frequency of the wheel and the contact between the blade and the grits creates stress on the wheel component. This project is proposed to analyze the fatigue life of the wheel component based on the original materials used to manufacture it. Focus on the fatigue study regarding the wheel component, the remote force approach is applied to simulation. Remote force approach helps in simulated force distribution as the blade component is set as a rigid body. This method help in studying the stress and deformation of a contact body which is the wheel component. This project mainly uses the Ansys software as the finite element analysis tools in order to determine the maximum stress from the static structural analysis. This approach helps in locating the high stress region within the wheel component that can be the factor that lead the component to fail. The static structural simulation give the results of maximum stress registered at a sharp edge within the design with the stress magnitudes of 103.17 MPa. Meanwhile, the fatigue analysis is done based on the static structural results to find out the total life cycles of the component. The maximum life cycle of the wheel component obtained to be around 10^9 cycles,with the mean stress amplitude of 61.882 MPa. Based on the results obtained, the data is correlates with the real life operation specifications to give out the maximum life of the wheel component to be 2 years and 104 days.

ABSTRAK

Sebuah mesin AutoBlast atau lebih dikenali sebagai mesin letupan empar, adalah mesin yang sering digunakan dalam proses kemasan permukaan logam. Di dalam sebuah mesin letupan empar terdapat sebuah roda yang mempunyai beberapa konfigurasi bilah yang berputar yang dikuasakan oleh motor elektrik. Roda yang mempunyai jisim yang berat ini berputar dan dibekalkan dengan media dipanggil bijian kasar, yang kemudiannya ditembak dalam halaju yang tinggi menurjahkan bijian kasar ke atas mana-mana permukaan logam. Oleh kerana kekerapan putaran yang tinggi, dan hubungan antara bilah dan bijiran kasar terhadap roda, mewujudkan tegasan pada komponen roda. Projek ini adalah dicadangkan untuk menganalisis hayat lesu komponen roda ini berdasarkan bahan asal yang digunakan untuk menghasilkan komponen tersebut. Projek ini terutamanya menggunakan perisian Ansys bagi pendekatan analisis unsur terhingga untuk menentukan tegasan maksimum daripada analisis struktur statik. Pendekatan ini membantu dalam mencari kawasan tekanan tinggi dalam komponen roda yang boleh menjadi faktor yang membawa kegagal sesebuah komponen. Sementara itu, analisis keletihan itu dilakukan berdasarkan keputusan struktur statik untuk mengetahui jumlah kitaran hidup bagi komponen. Simulasi struktur statik memberi keputusan tegasan maksimum didaftarkan di kawasan yang tajam di dalam reka bentuk dengan magnitud tegasan 103,17 MPa. Sementara itu, analisis keletihan itu dilakukan berdasarkan keputusan struktur statik untuk mengetahui jumlah kitaran hidup bagi komponen roda. Kitaran hayat maksimum komponen roda yang diperolehi sekitar 109 kitaran. Dengan purata tegasan amplitud tekanan 61,882 MPa. Dan dengan berdasarkan keputusan, data yang diperolehi, Dapatan dihubung kait dengan spesifikasi operasi kehidupan sebenar untuk memberi jumlah kitaran hidup yang maksimum bagi komponen roda adalah 2 tahun dan 104 hari.

Table of Contents

List of Figure

List of Table

List of Equation

CHAPTER 1

INTRODUCTIONS

1.1 Overview

Blasting or blast cleaning is one of the vital process in any fabrications industries. This process helps in providing effective surface preparation as one of the essential stage for steel treatment before any coating or even fabrication procedure can begin. The surface preparation includes, paint removal, cleaning of mil-scale and rusted surfaces thoroughly. This is due to the fact that the performance and quality of a surface finish is depending on the ability of the coating to adhere to the substrate materials. The blasting process can be made available for a small or even large scale fabrication project. An automatic blast cleaning has the capabilities to handle larger work piece while the conventional manual blast cleaning can handle a much more remote or smaller work piece.

The idea behind the blast cleaning process are not just fall under the cleaning process scope. In providing a better surface finish, the blast cleaning process also have to provide a consistent surface contour for the work piece. The tolerance for thickness of the work piece also can be varied based on specific requirement. The standard requirement can refer to the accordance of BS EN ISO 8501-1 as follows:

- Sa 1 - Light blast cleaning
- Sa 2 - Thorough blast cleaning
- Sa $2^{1/2}$ - Very thorough blast cleaning
- Sa 3 - Blast cleaning to visually clean steel

These requirements can be obtained based on the speed of the rotating wheel that can throw the grit based on specific angle and the size of grit use in the process. The mechanism is much simple to understand but if the whole process and equipment is not monitored gradually, the whole process can go awry.

The main component inside the automatic blasting machine is the wheel. The wheel consists eight blades that rotates in high revolution creating substantial force throwing the media or grit onto the work piece. the area of grit shear coverage can be adjusted based on the distance between the wheel to the work piece. The nearer the wheel to the work piece, the smaller the girt shear area. The blasting depth on the surface of the work piece can be control based on the type of grit and the size of the grit.

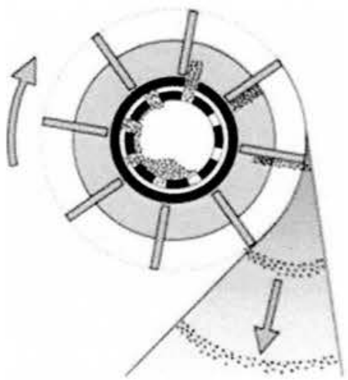

Figure 1.1: The Wheel Mechanism[3]

It is becoming a vital step in providing preventive maintenance for these automatic blasting machine in order to prevent from halting any production lines as the wheel configuration is the heart of the whole process. Rotating in high velocity, filled and throwing the media to the work piece can cause deterioration to wheel and lead to failure if the machine is not being handled or been used overtime. Thus a more advance way can be approached to provide better analysis on the life span of the wheel configurations, providing a better preventive measure to aid the whole process from shutting down due to catastrophic incident.

1.2 Problem Statement

The rotating wheel of the automatic blasting machine is the main component that is being subjected to numerous loads. A great deal of attention is therefore paid to provide reliability and avoid catastrophic failure. This failure if occurred, may results in high material cost and possibly halt any productions line. Besides that, a better proactive approach should be highlighted in order to provide a better quantitative measure. For example, the life span of the component based on strength and material properties used to fabricate them. This is due to the fact that there are numerous materials that can be used to fabricate the wheel component. But in terms of strength and integrity of the material to withstand the load is rarely being identified clearly. The material selections are crucial for the wheel component. Therefore, it is extremely important to highlight the area that can cause damage or even any factor that can lead to the failure of the wheel component to ensure that a suitable preventive maintenance can be plan to keep any heavy production up and running base on their respective periods.

However, the problem with fatigue analysis of the wheel component is it often involve many factor and parameter that need to be considered. This is due to the fact that the stress and pressure exerted to the wheel is mainly determined by the feeds of the media. In this case is the grit. The size and volume of the grit that being feed into the wheel system can be fluctuates against time causing uneven stress distributions. Besides that, the inconsistency of the media feed can cause the rotation to be imbalance and the blasting action can be too aggressive that it hurt the wheel physically. There are many factor that need to be consider in using the finite element analysis approach to solve the problem. This includes the proper input of the material properties, the pressure exerted within the wheel, operation hours in every productions line and also the rotation of the wheel in producing the blasting power. These factor need to be taken into account, in order to get an accurate results based on the law of physics.

1.3 Motivation and Objective

In the year 2013, MMHE (Malaysia Marine and Heavy Engineering) have encountered a problem where their primary automatic blasting machines, that often broke down due to the wheel malfunction. As been stated by the operation manager, they had been told that the original wheel component would last around six years, but based on the current situations, the wheel component only last around two to three years. This is a concern that arise because any product that comes with an original equipment supposed to last a little longer compare to the half of its life span. Thus the aim of my project are to examine the factor that cause the original wheel to fail much quicker compare to the stated life span. The details are as follows:

- To find the stress concentration area acting on the wheel component using finite element analysis
- To impose the wheel under cyclic loading to find the fatigue analysis using finite element analysis.

1.4 Scope of Project

The wheel component will undergo fatigue analysis with the application of the Ansys software under the finite element analysis scope. The procedure will include:

- A modeling of the wheel component using Solidwork software based on the accurate dimension
- To evaluate the wheel dimension and profile based on the original component
- Literature research to understand the mechanism of the automatic blasting machines and also the properties of the material use with S-N life diagram
- Simulation using Ansys Software under the static structural to locate the stress concentration point
- Fatigue analysis simulation using the Ansys software based on all the parameter that are been gathered
- Make a design to improve and compare the data from the simulation as a benchmark for a conclusion on the life span of the automatic blasting wheel component.

1.5 Organization of report

This report presents the fatigue analysis base on finite element analysis using the Ansys software. Chapter 1 of this report is the introduction, covering the overview, problem statement, motivation and aim of the project and scope of the project. Chapter 2 will emphasize on the literature review, relevant theory of the centrifugal blasting that will include the mechanism of the machines. Follow by chapter 3 where the methodology and approach to the project will be given in details. A brief procedure on how fatigue analysis been conducted will be presented through the methodology chapter. The following chapter shall present the results and discussion obtain from the simulation and a prototype design to improve the current design. Lastly, a brief conclusion is included to summarize all the theories and findings presented.

CHAPTER 2

LITERATURE REVIEW

The beginning of the industrial revolution era pushes human to produce bigger, taller and heavier man made marvels to the world. The rapid growth of need for prepared materials pushes every industrial field to equip themselves with bigger and better equipment such as the automatic blasting machines. In every equipment there is a main component that have a vital role in keeping the machines functions. In this case it is the centrifugal wheel. Maintaining the wheel component within its life span can ensure better preventive maintenance approach. This chapter is dedicated to review the development and some original patent and why does certain approach is being used. Besides that, in this chapter the factor that need to be considered for the studies of fatigue analysis will also be reviewed. This can help in providing better understanding throughout whole project.

2.1 Original Wheel Patent.

The original idea behind the invention of sand blasting process can be traced back to the year 1869 by Mr Benjamin Chew Tilghman. Who later patented it in the United States of America by the patent number of US 104,408. The application in which uniquely suited for sharpening files, engraving bottles, cleaning boiler or bringing out the grains out of the wood. Later the idea become a company that specialized in sand blast in the years of 1879 under the name Wheelabrator Tilghman. Most of Wheelabrator patents became one of the important benchmark model for the innovation of other blasting machines. Later in the year 1984 an inventors named Van Huyssteen and Jan Hendryk Hormeyr addressed their idea for a simpler arrangement of the blasting machine. His idea basically to improve the design for the ease of servicing process also for better efficiency in operation. Based on his patent (EP 0144215 A2) title *shot blasting wheel*, his idea was to redesign the wheel by introducing a groove for a much simpler blade replacement process. The blade is then being kept in place using a lock. Figure 2.1 shows the original schematic patent of the blasting wheel.

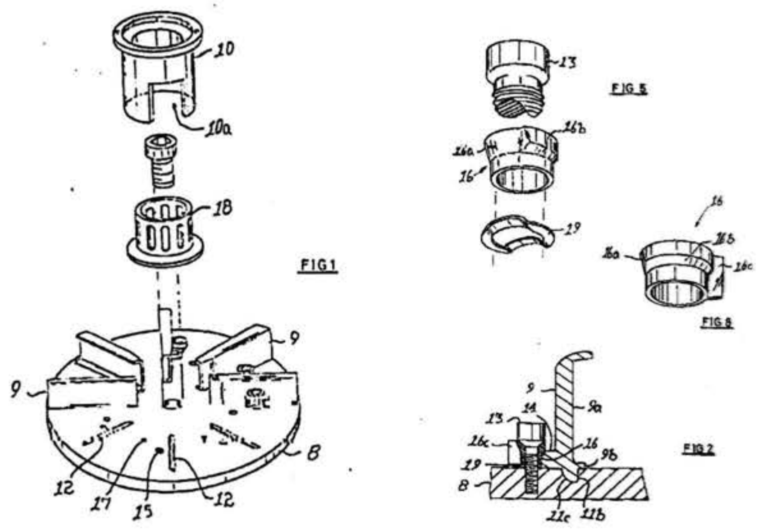

Figure 2.1: Van Huyssteen and Jan Hendryk wheel and blade configuration. [23]

2.2 The Mechanism of the Automatic Blasting Machines.

The automatic blasting machines are designed to throw or shot a media in high velocity towards a surface. This media used is called grit. The grit can either be a steel or copper based grits. Based on Tim Heston in his article *The Basic of Wheel Blasting,* the grits come in various sizes. This size depends on the type of surface that the machines are dealing. A.W. Mallory explain in *Guidelines for Centrifugal Blast Cleaning*, the blasting process starts as the wheel inside the wheel cabinet begin to rotate in high speeds. Next, as refer to Figure 2.2 the grits then feed form the top into the wheel cabinet. The grit traveled into the distributor and align to the blades. As the blade rotates, the grits are being thrown or shot in high velocity to the surface of the work piece.

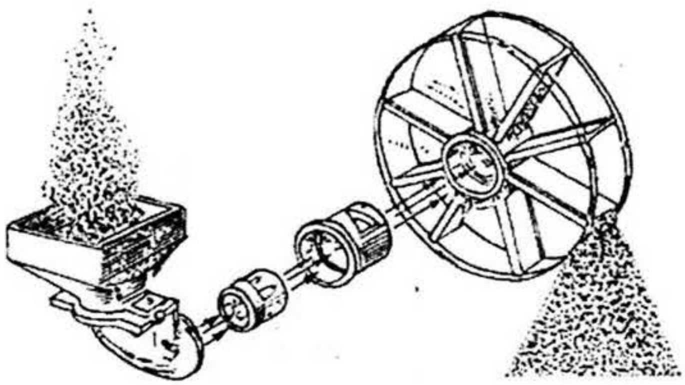

Figure 2.2: The Schematic Diagram of Automatic Blasting process. [16]

This centrifugal blast cleaning uses motor to rotates the bladed wheel in high speed. The abrasive or grits is propelled by this bladed wheel, which utilize the combination of radial and tangential forces to impart the necessary velocity to the abrasive. Based on Figure 2.3 the position of the wheel from which the shot is projected can be adjusted to help concentrate the blast in the desired direction. Among the advantages of the wheel method, the shot velocity can be controlled in order to get the specific requirement for a surface finish. Based on the book entitle *Guidelines for Centrifugal Blast Cleaning*, the typical setup for steel cleaning system uses, 300 millimeter in diameter of wheel driven at 2250 revolution per minute by 30 horse power motor will provide grits velocity of approximately 14,400 feet per minutes or 73.152 meter per second with a responding flow rate of about 800 pounds or 363 kilogram per minutes of steel grits [3].

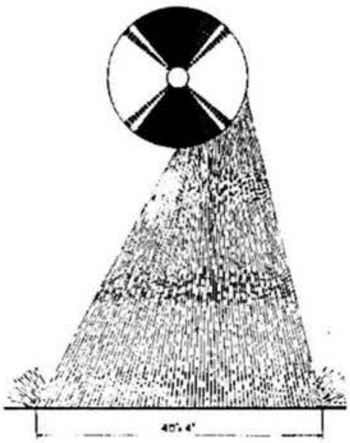

Figure 2.3: The concentration blasting area.[19]

2.3 Material Specification and Properties.

The wheel of a shot blast machines are known for being more versatile in allowing for a wider range of parts, production output and finish requirements. In addition, the wheel component is available in numerous design configurations and capacity sizes for low or high production parts requirements. Besides that, for the type of grits, most manufacturers use small steel shot media which offers a fine profiled consistent finish. Other media such as steel grit, stainless shots and grits, aluminum shot as well as plastics or organic medias such as fruit pits and shells of nuts are also known to be used. A properly configured and sized wheel blast machine is capable of propelling a much greater volume of media, which in turn creates shorter cycle times and ultimately higher production output [6].

The material selection to manufacture the wheel need to have a sustainability property to ensure that the material can endure the force acting on it. The conventional material choices would be the carbon steel. More specifically the AISI 1045 medium carbon steel. These material are widely used to produce gear and shaft with a higher ware resistance [17]. Table 2.1 display the physical and mechanical properties of AISI 1045 medium carbon steel.

Table 2.1: Physical and Mechanical properties of AISI 1045. [17]

Physical Properties

Physical Properties	Metric	Imperial
Density	7.87 g/cc	0.284 lb/in³

Mechanical Properties

Mechanical Properties	Metric	Imperial
Hardness, Brinell	163	163
Hardness, Knoop (Converted from Brinell hardness)	184	184
Hardness, Rockwell B (Converted from Brinell hardness)	84	84
Hardness, Vickers (Converted from Brinell hardness)	170	170
Tensile Strength, Ultimate	565 MPa	81900 psi
Tensile Strength, Yield	310 MPa	45000 psi
Elongation at Break (in 50 mm)	16.0 %	16.0 %
Reduction of Area	40.0 %	40.0 %
Modulus of Elasticity (Typical for steel)	200 GPa	29000 ksi
Bulk Modulus (Typical for steel)	140 GPa	20300 ksi
Poissons Ratio (Typical For Steel)	0.290	0.290
Shear Modulus (Typical for steel)	80 GPa	11600 ksi

2.4 The Effect of Shot Blasting Grits to the Wheel Component.

The main problem that affects a shot blasting wheel is that it suffers from the same effect that the thrown abrasive causes on the surface to be treated, which is the wear or wearing out. Wear is the key problem to solve when deciding which wheel and which abrasive should be used together. On most shot blasting applications round steel shot or soft steel grit hardness (45 to 50 HRC) are used, and generally shot blasting wheel can cope with it with reasonable success as far as wear is concerned. Figure 2.4 shows the steel grit type based on hardness levels, different situations take place when there is a need to use medium hardness (52 to 56 HRC) or high hardness (> 64 HRC). In those specific applications, as for example, surface preparation prior to metalizing by zinc wire, or roll etching of laminator cylinders, the wear caused on shot blasting turbines is so high that in some hours the wear caused on the wheel part will disrupt the abrasive jet direction, reducing dramatically the blasting performance and causing important damage on the shot blasting wheel [12]. Another frequent problem on foundry shot blasting machines is the shock of the castings with the wheel blades. Due to the geometry of the castings, most of them blasted with the feeding channels, it is frequent, and in most cases unavoidable and unpredictable, the shock of some of the castings or its feeding system with the wheel blades. This shock at a speed that most time runs at around 3.000 rpm, has a tremendous impact on a blade, breaking it, mainly those made of hard metals which are naturally fragile. This causes not only the loss of the blade, but usually also affects other parts of the turbine and frequently the adjacent turbines in the case of multiple turbines shot blasting machines [12].

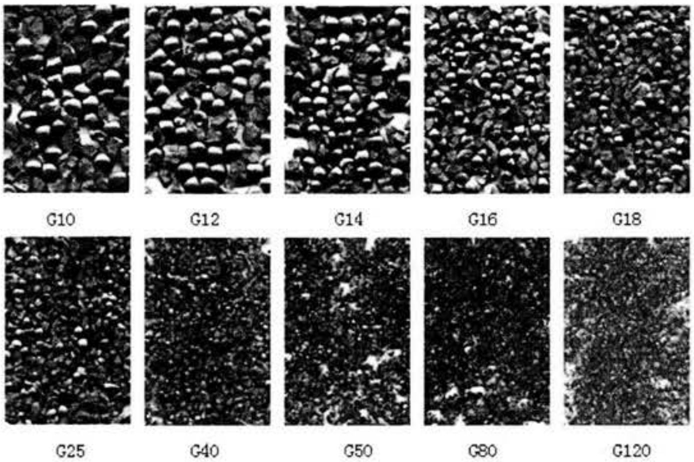

Figure 2.4: Steel Grit Type based on Hardness level. [5]

2.5 The Relationship Between Size of Grits and Force Induce by Bladed Wheel.

Katsuji Tosha (2008) described the relation the grits size and amount of force generated to thrown the grit on to the surface of the work piece. In particular, the size range can be between (0.55-2.2 mm) and the grit travel in the velocity ranging between (15-35 m/s). In his studies he stated that by using the kinetic energy approach the force generated in every cycle depends on the cohort movement and the mass of every cohort carries in each cycles [13].

David Krik (2007) further described that the cohort movement and the force generated are related to the mass of each cohort. He explained that, if given a 400 cohort movement per second. And the machine throwing 120 kilograms per minutes that is 2 kilograms per second. Divide the 2000 gram with 400 cohorts, it will give us 5 grams per cohort [10]. Theoretically, by using the kinetic energy formula, the force acting on the blade can be calculated as follows: