FINITE ELEMENT ANALYSIS OF WELDED CIRCULAR THIN WALL STRUCTURE

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for the award of the degree of
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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurently submitted for award of other degree.

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ABSTRACT

This project is using finite element model (FEM) to analyze welded circular thin-wall structure. Finite Element Analysis (FEA), Algor, was used to simulate the static, dynamic, temperature and also different loading conditions. The major problem in this thin walled structure usually happens in exhaust part of car body. This part referring to the problem, the weld portion will be analyzed using FEA to estimate maximum temperature that can be applied before failure. After completed the analysis using FEA, an experimental was carried out. Stainless Steel types 409 will de welded using Tungsten Inert Gas (TIG). Temperature was taken using Laser Temperature Sensor. Comparison was made between FEA and experimental data. The final result shows discrepancies about 35.54%. However, the structure was still in safe condition since it has not exceeded the maximum temperature of that material.

ABSTRAK

Projek ini menggunakan model Finite Element untuk menganalisis struktur dinding nipis yang telah dikimpal. Finite Element Analysis (FEA) sebagai contoh ALGOR, telah digunakan untuk mengsimulasi keadaan statik, dinamik, suhu dan juga perbezaan beban. Masalah utama dalam applikasi struktur dinding nipis yang telah dikimpal biasanya terdapat pada bahagian kereta, iaitu ekzos. Bahagian ini merujuk kepada masalah dimana bahagian yang telah dikimpal akan dianalisis menggunakan FEA untuk menganggar suhu maksimum yang boleh dikenakan sebelum struktur tersebut gagal. Setelah selesai proses menganalisis menggunakan FEA, eksperimen akan dijalankan. Stainless Steel jenis 409 akan dikimpal menggunakan Tungsten Inert Gas (TIG). Suhu akan diambil menggunakan Laser Temperature Sensor. Perbandingan akan dibuat diantara data FEA and data eksperimen. Keputusan akhir menunjukkan perbezaan dalam 35.57%. Walau bagaimanapun, struktur tersebut masih dalam keadaan yang selamat selagi tidak melebihi suhu maksimum bahan tersebut.

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LIST OF ABBREVIATIONS

FEA	Finite Element Analysis
FEM	Finite Element Model
TIG	Tungsten Inert Gas

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

There is a worldwide trend to use more computer simulation during the development phase of new vehicles, in order to improve structural behavior and decrease the time to market and costs. Accurate finite element model must be generated in order to predict the system structural behavior and to allow fast optimization processes. This work shows the CAE procedure applied to welded circular thin-wall structure.

1.2 PROBLEM STATEMENT

In automotive industry, several problems arise based on the application of welded circular thin-walled structure in exhaust system**.** Major problem is exhaust system presented failure in the welded region within the primary tube and its bracket, forcing the test interruption. Others problem, automotive exhaust pipes are required to be thin-walled from standpoint of energy and weight reduction, and yet they have to satisfy stringent requirements such as endurances, corrosion resistance and heat resistance. The aim of this work is to identify the possible causes of the failure and suggest the appropriate method to analyze this problem.

Generally, to suggest and to solve the problem related to industrial field, especially in analysis of structure, we should know the advantages of the welded circular thin-walled structure in order to improve the strength of the structure to ensure it is safety to user.

1.3 OBJECTIVES

1.3.1 To analyze the strength of the welded circular thin-wall structure using Finite Element Analysis (FEA)

1.3.2 To analyze the strength of the welded circular thin-wall structure using Laser Temperature Sensor

1.3.3 To compare the result between software analysis and experimental analysis.

1.4 SCOPE OF STUDY

This project, emphasis only on the welded circular thin-walled and Finite Element Analysis. Experimental analysis is just an additional method performed to compare the data between theoretical and experimental analysis since the previous researcher never analyze the welded circular thin walled on exhaust structure. However, in order to make the project run smoothly, scopes have been determined to guide and to prevent any misleading. Scopes of this project are as below:

1.4.1 Application of weld circular thin-wall structure in industrial field

1.4.2 Finite Element Analysis (FEA) Software

1.4.3 Welding Process using Tungsten Inert Gas (TIG)

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Thin-walled structures are widely used in automotive industry and aircraft industry for the purpose of increasing energy absorption efficiency, weight reduction, cost reduction and safety as well as reliability. Beside the thin-walled structures, circular thin-walled are also important structures widely used as structures in lightweight vehicle design especially in exhaust systems. Recently, worldwide trend emphasis to use more computer simulation during the development phase of new vehicles, in order to improve structural behavior and decrease the time to market and cost. Accurate Finite Element Model (FEM) must be generated in order to predict the system structural behavior and to allow fast optimization process [1].

2.2 EXHAUST SYSTEMS

The function of exhaust system is cleans the exhaust gases from engine in quiets operation. The system carries the gasses to the rear of the car and discharges them into the air. Exhaust structure usually build from thin wall structure such as stainless steel, aluminum or carbon steel [2]. Since the exhaust structure build from that kinds of materials, especially the tail pipe, the strength of the structure have to be consider, especially at the structure that have a welding portion to connect between tail pipe and flange.

2.2.1 Exhaust System Operation

The purpose of a vehicle exhaust system is to:

a. Carry exhaust gases from engine.
b. Reduce the noise level of the engine.
c. Protect the vehicle occupants from noxious exhaust gases.
d. Reduce the environmentally polluting emission.

The main parts of a vehicle exhaust system include:

a. Exhaust manifold or manifolds
b. Exhaust pipes
c. Flexible exhaust decouplers
d. Catalytic converter or converters and oxygen sensors.
e. Muffler or mufflers, and resonator on some systems.
f. Exhaust hangers.
g. Exhaust clamps, on systems with slip-fit pipes.
h. Heat shields

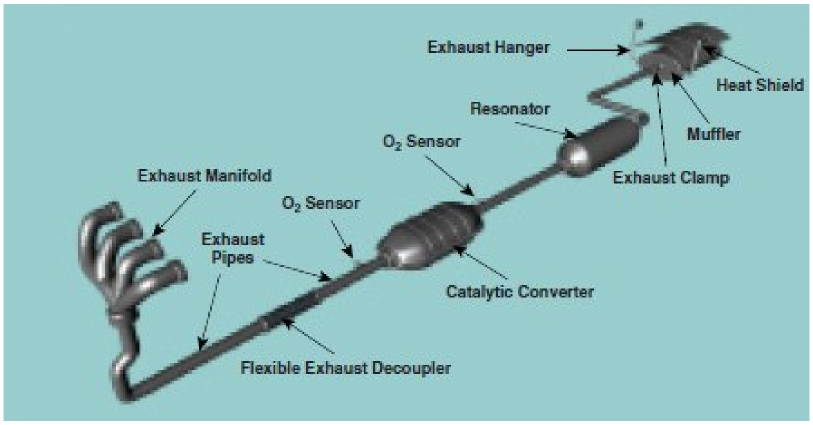


Figure 2.1 This illustration shows the main parts of a typical exhaust system

Source: Walker 2000

2.2.2 Type of Exhaust Systems

Single exhaust systems have one exhaust path from the engine consisting of a single exhaust pipe and muffler. Engines of with a "V" or opposed design will a "Y" pipe to combine both exhaust banks into one pipe.

Dual exhaust is typically used on V-6 or V-8 engines where performance is an issue as it creates less back-pressure than a single exhaust [3]. Dual exhaust systems have two exhaust paths from the engine, one for each side or bank of a "V" design engine. Dual exhaust will have two catalytic converters, mufflers, and exhaust pipes. Dual exhaust systems may have a crossover between two exhaust paths to equalize the pressure between them. Figure 2.2 presents typical single exhaust systems.

Figure 2.2 This is an example of typical single exhaust systems

Source: Chrysler Corporation 2001

Exhaust systems also may be made up of individual parts that may be removed in sections. The exhaust parts maybe bolted together through flanges. The flanges may be flat and require a gasket between them to seal, or there may be an insert on one flange that seals into the other flange without a gasket. The exhaust parts may also be held together by a slip-fit and a clamp. On this design, the downstream pipe will be slightly larger than the pipe it attaches to. The two pipes are slid together and a clamp is used to tighten and seal the connection.

A one-piece design from the converter back. On this design, the mufflers and resonators are welded to the pipes that connect them to the forward part of the exhaust system (See Figure 2.3 and 2.4). This one piece assembly is typically attached to the converter with a flanged and bolted connection. Factory welded stainless steel exhaust systems are welded with AISI 409 stainless steel filler material to control corrosion at the weld zone.

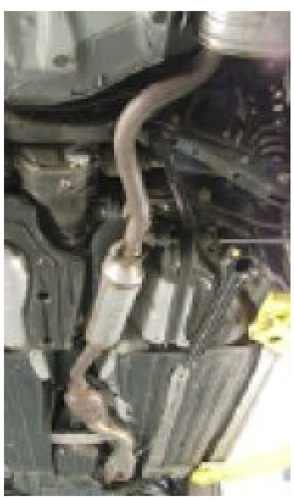


Figure 2.3 Welded constructions from catalytic converter back

Figure 2.4 Individual parts bolted together through flange

Source: Chrysler Corporation 2001

2.2.3 Exhaust System Service

Considerations when servicing exhaust systems include:

a. Exhaust part can be very hot if the vehicle has been running.
b. Exhaust gas is poisonous. Never run a vehicle in enclosed area for extended time periods
c. Exhaust part may be stainless steel or carbonized. When replacing parts on a stainless steel or carbonized system, the replacement parts should be constructed of the same material to match the corrosion resistance of the original exhaust.

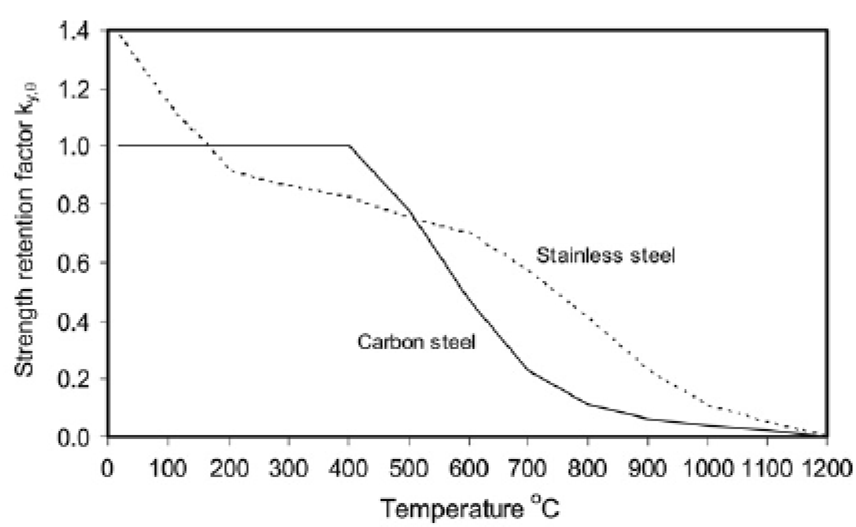
Some additional considerations for servicing exhaust systems include determining the attachment method for the replacement part. The attachment method used for the replacement or service part should match that of the original part if possible. However, the attachment method may be dictated by the design of the service part. Some one-piece factory systems are not serviced as one-piece units and will have service parts that are designed to be attached by slip-fits and clamps. If welding of exhaust parts is necessary, use the correct electrode wire and shielding gas for the application. Stainless steel exhaust parts should be welded with AISI 409 stainless steel electrode wire and a 98% argon 2% oxygen gas blend. Welding on aluminized exhaust parts may burn the protective coating off creating a corrosion hot spot [4].

When using heat on exhaust connections and fasteners:

a. Use only as much heat as required loosening the fastener.
b. Only heat the removable part of the fastener. Avoid excessive heat on the pipes or pipe flanges.
c. Replace the part of the fastener that was heated with a new part.

2.3 MATERIAL PROPERTIES

Stainless steel has many desirable characteristics which can be exploited in a wide range of construction applications. It is corrosion-resistant and long-lasting, making thinner and more durable structures possible. It presents architects with many possibilities of shape, color and form, whilst at the same time being tough, hygienic, adaptable and recyclable. The structural performance of stainless steel differs from that of carbon steel because stainless steel has no definite yield point and shows an early departure from linear elastic behavior with strong strain hardening [5]. There can also be significant differences between the stress–strain curves for tension and compression. In a fire, austenitic stainless steel columns and beams generally retain their load-carrying capacity for a longer time than carbon steel structural members. This is due to their superior strength and stiffness retention characteristics at temperatures above 500˚C (Fig. 2.5).



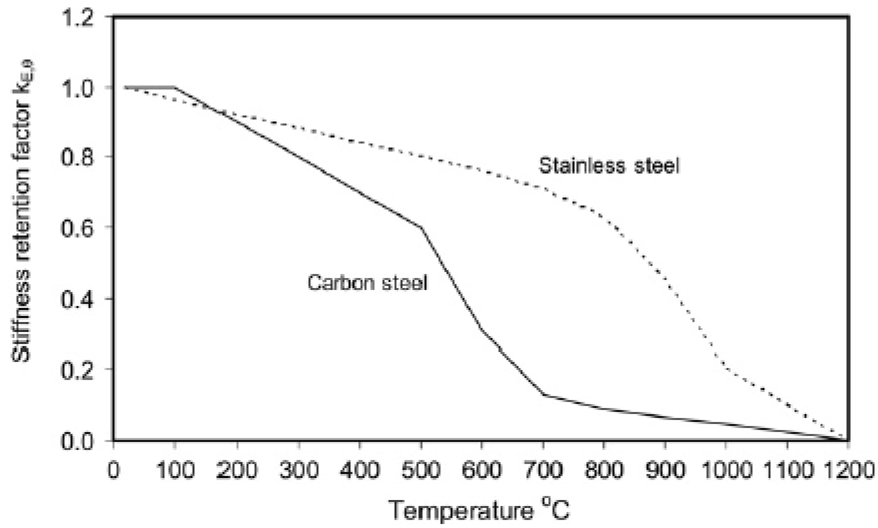


Fig. 2.5 Comparison of stainless steel and carbon steel strength and stiffness retention factors (grade 1.4301 stainless steel, strength at 2% strain for both stainless and carbon steel).

Source: N. R. Baddoo 2008

2.4 FINITE ELEMENT ANALYSIS

The finite element method is a an approximate numerical analysis technique for solving the differential equations of engineering and physics in which the behavior of a physical structure is analyzed by replacing a continuum with a mesh consisting of a number of small discrete entities called finite elements joined by shared nodes. The continuous variables representing physical quantities are replaced by the values of these variables at the nodes, and the continuous functions representing the relationships among the variables are replaced by piecewise approximations, usually polynomials. Thus, the first main step in a FEA and simulation is this process of discretization [6].

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The accuracy of the numerical solution can be improved by increasing the mesh density, i.e., increasing the number of finite elements used, resulting in a simulation representing the actual physical structure more closely. When a structure is broken down into many small simple blocks or elements, the behavior of an individual element can be described using a relatively simple set of equations. Just as the set of elements would be joined together to build the whole structure, the equations describing the behaviors of the individual elements are combined into a very large set of equations and corresponding matrices that describe the behavior of the structure as a whole. In recent decades, the finite element procedure has become one of the most powerful and widely used in analyzing and solving a large variety of engineering problems, such as stress analysis, metal fatigue, heat transfer and fluid mechanics, and in a diverse range of practical applications from aircraft design to earthquake studies.

However, as with other mathematical procedures, and except for specialized cases, engineers and researchers are no longer required to write lengthy computer programmes as part of their work. A whole host of mathematical procedures from matrix multiplication to million-line computer codes are now available as convenient, ready-made, general- purpose software packages. In addition to providing the numerical solution, modern software provides a convenient, usually window-based, user interface to enter the required data and display the output [7]. More sophisticated packages also provide a functionality to design and draw complex geometries in three dimensions. A large number of highly-developed FEA software packages are now commercially available.

In general, FEA consists of three main stages: preprocessing, processing and post-processing. Preprocessing consists of modeling the practical problem to be solved, and includes such aspects as creating the geometry, entering the input data, for example, material properties, and meshing the model. Processing is the main stage and provides the numerical solution of the equations that represent the relationships among the stress, strain and other variables and produces the values of the fundamental variables. Post-processing is the stage, where the results are plotted and interpreted, and additional variables calculated.

2.4.1 Applications area of FEA

In order to use FEA software in analyze the failure, generally, the application of FEA cover in structural analysis static and dynamics, heat transfer, electromagnetic, fluid flow, soil mechanics, aerodynamics acoustic and many more.

2.4.2 Analysis Type

In analyze for this project, analysis types available in ALGOR will be focused. It is the first decision to choose depending on the parameter of interest. The analysis type will dictate what type of results that will obtain.

However, in order to achieve the objective using finite element analysis to analyze weld circular thin-walled structure, thermal analysis will be use to analyze the heat transfer due to transient heat transfer [8].

2.4.3 Advantages of FEA

Generally, FEA can be used to analyze problems involving:

i. Irregular geometries
ii. Different material properties
iii. Various boundary conditions
iv. Variable element types and size
v. Easy modification
vi. Nonlinear and dynamics

2.5 TUNGSTEN INERT GAS (TIG) WELDING

Tungsten Inert Gas (TIG) welding has been used in modern industry, especially for welding hard-to-weld metals such as stainless steel, titanium alloys and other materials for high quality weld. TIG welding process has some advantages, including high quality, easy and precise control of welding parameters. As a result, TIG welding has mainly used for welding the workpiece with thickness less than 6 mm. TIG welding which uses a nonconsumable tungsten electrode an inert gas for arc shielding, is an extremely important arc welding process.

Basically, TIG weld quality is strongly characterized by the weld pool geometry. This because the weld pool geometry plays an important role in determining the mechanical properties of the weld. Therefore, it is very important to select the welding process parameters for obtaining optimal weld pool geometry [9]. The schematic diagram of the TIG welding process is shown in Fig. 2.6 A non-consumable tungsten electrode,

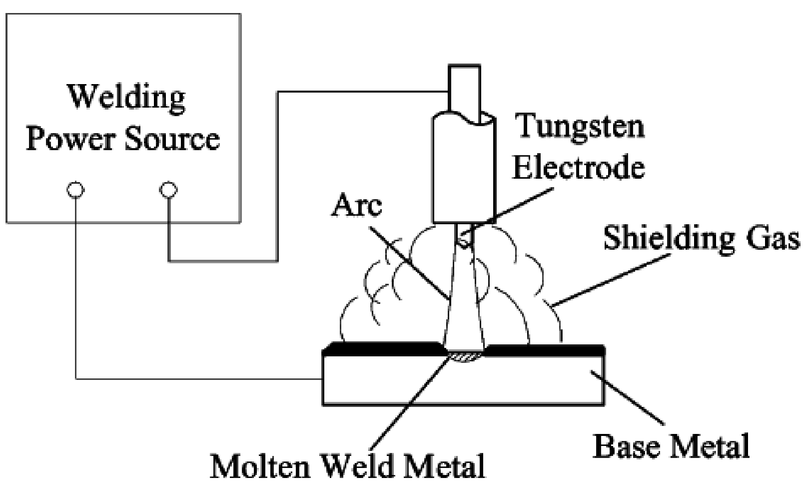

Fig. 2.6 Schematic diagram of the TIG welding process

Source: Millerwelds, 2006