A Study on Modelling and Optimization of Alloy Wheel

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Abstract

A great number of wheel tests are required in designing and manufacturing of wheels to meet satisfactory requirements. . This has motivated the need for an optimization tool that uses an inverse modelling approach to determine these parameters, given appropriate experimental measurements. Optimization strategies are used to tune computational models to plant conditions. These wheel models are then used in a second phase of optimization that improves the operation of the casting plant thereby playing a major role in reducing costs and improving productivity and quality of cast products. The use of numerical optimization and modelling has been demonstrated to predict casting phenomenon at macroscopic scales, with very successful predictions for directions of improvement.

Keywords: *Optimization, alloy wheels, molten metal, finite element analysis*

1. Introduction

1.1. Background

In a car every component is important but some are more critical than others. Components which may fail but will not cause fatal accidents are not catastrophic in failure. The car electrics are an example of this Wheel, breaks, steering or tyre failure, on the other hand, can cause catastrophic accidents in failure. Road wheels are one of the most important safety components from a structural point of view. They are required to be lighter and more attractive to the customer all the time. This means that it has become necessary to perform more rigorous strength evaluations on new wheel designs.

1.2 Wheel design

The designer must keep the following in mind when designing a new wheel.

- The wheel is required to be an aesthetically pleasing feature of a car
- It is classified as a safety component of a vehicle.
- It is a very highly stressed safety component.
- Modern car manufacturers have to meet very strict reliability specifications.
- Fuel consumption must be reduced to a minimum, this means that cars must be as light as possible, because these two factors are directly related.
- They are required to recycle as much of the material used in the product as possible and keep all manufacturing costs to a minimum.
- Car companies are producing cars with a reduced design cycle time.

All these factors lead to a very competitive design process. To ensure the future of the manufacturer it is now vital for them to be able to produce the component quickly, inexpensively with a proven design approach which satisfies the required reliability. Another important parameter relevant to fuel consumption is the vehicle weight. The

achievement of an optimum weight without safety penalties is only possible, however, in conjunction with an optimization of the component strength.[1]
The use of a light alloy wheel minimises weight and fuel consumption. They have high strength and rigidity characteristics and good fatigue resistance. They can be easily manufactured. They allow a very high level of recycling and have a high resistance to corrosion. Aluminium alloys have the best combination of all these requirements. Alloy is an excellent conductor of heat, improving heat dissipation from the
brakes, reducing the risk of brake failure under demanding driving conditions.[2]
The recent introduction of alloy wheel for car, which has more complicated design and shape than a regular shape, needs prediction of fatigue life by analytical methods rather than a regular test. Limited research has been carried out on the analysis of wheel disc using finite element analysis[3]
Manufacturing is the backbone of any industrialised nation. Its importance is emphasised by the fact that, as an economic activity, it comprises approximately one third of the value of all goods and services produced in industrialised nations. The economic health of a country is directly related to its level of manufacturing activity. The higher the level of manufacturing activity in a country then, generally, the higher is the standard of living of its people. So, what is manufacturing? Manufacturing can be broadly defined as the process of converting raw materials into useful products. Manufacturing changes the form of materials, using various processing techniques, to create useful products. As a result of the number of changes in form of the raw material during processing, the manufactured product has a value greater than that of the raw material.[4] At each stage of the manufacturing process, in which the usefulness of the raw material is improved, the value of the item increases. For example, raw materials needed for the production of steel wire have a certain value when mined. As the raw materials are processed into steel wire a useful product is created with a value higher than that of the raw materials. Further processing of the steel wire into nails or coat-hangers increases the value of the product again.
A manufacturing system coordinates elements of input, process and output. Input in a manufacturing system includes consumer demand, material, money, energy, human resources and education, whilst process includes design, production and management. A combination of input and process in a manufacturing system result in output. Examples of output include; goods, capital goods, satisfaction, quality and cost effectiveness. As consumer demand is an input into manufacturing systems it makes sense that for a manufacturer to remain viable it must satisfy consumer demand or be left behind as those demands are met by other manufacturers. One particular example of consumer demand is more rapid fulfilment of customer orders, i.e. reduced lag time between an order being placed and a quality final product being received. Most factories use a push system approach to plan and build products to fill customer orders.[5] A push system approach is to build to order, which means that when an order arrives at the company it creates a demand to manufacture the product according to how the customer wants it. This type of manufacturing approach creates a long lead time for delivering the product because manufacturing does not commence until after the customer has placed the order. In order to reduce the time between commencement of manufacturing and delivery to the customer, it is necessary to reduce the amount of time that a product spends in process. This can be achieved through reducing the processing time of the product at individual stages of manufacturing. Improvements in productivity can be described as changes in operating cycles and processes that result in the production of more items at equivalent or lower cost or the production of the same amount of items at a lower cost. This also extends to changes in operating cycles and processes to ensure a better quality product at the end of production. [6]Ultimately, the objective of productivity improvements is the production of more items with higher quality at a lower cost. This particular objective is something that modern manufacturing organisations endeavour to achieve.
Two parameters that have a substantial influence on productivity improvements within a manufacturing organisation are process planning and product flow. Planning of

manufacturing activities is necessary for a manufacturing operation to be efficient. Process planning determines the required operations and necessary facilities to manufacture a part or product. It is concerned with selecting methods of production, tooling, fixtures and machinery, sequencing of operations and assembly[7]. Two aspects of process planning are specification of a suitable production schedule and determining production speeds for minimum cost and maximum production rate. Process planning determines product flow within a manufacturing system. Product flow is the flow of product throughout the manufacturing system from initial to finished product. Factors that influence product flow are the sequencing of necessary production operations to give the most efficient process, plant layout and the ordering of operations such that necessary tasks are completed in the correct order of processing.[8] Product flow analysis assists in achieving the most economical use of floor space and is used to assess sequencing of operations to determine the optimum arrangement of equipment. In its broadest sense, product flow is used to analyse products flowing through a plant and assess the most appropriate paths and sequencing of events. The study of product flow within a manufacturing environment involves the optimisation of a problem by analysis of all the options and alternatives within the problem. It is very important that the focus of the problem remains the desire for an increase in productivity. There is a need for understanding product flow and process planning as a part of controlling and optimising overall production time and production rate. Without efficient product flow productivity cannot be optimum. Improvements that arise from product flow analysis contribute to the productivity improvements of the operation. Flow of materials and components throughout a manufacturing system is greatly affected by plant layout.[9] Due to the increasing desire to improve productivity in manufacturing systems automation is becoming increasingly popular. Automation is the process of following a predetermined sequence of operations with little or no human labour, using specialised equipment and devices that perform and control manufacturing operations.[10] This is achieved with various devices, sensors, actuators, techniques and equipment that are capable of observing the manufacturing process, making decisions concerning the changes that should be made in the process and controlling all aspects of the processing operations. The major goals of automation in manufacturing facilities are to integrate various operations to improve productivity, increase product quality and uniformity, minimise cycle times and effort, reduce labour costs, reduce possibilities of human error and raise the level of safety for personnel. In addition, material handling and material movement are also popular areas subject to automation in manufacturing plants.. Automation of material handling also has benefits not immediately recognisable as productivity improvements. For example, operations involving human beings can be unpredictable, unreliable and also unsafe for the operator depending on the conditions under which the operations are being carried out. For this reason, automated material handling is advantageous. Automated material handling also leads to the desired effects of improved repeatability and lowered labour costs. [11]

A study of a modern manufacturing organisation such as the one detailed in the following literature is useful to highlight the need for productivity improvements in a manufacturing system and emphasise the extent to which automation can accompany these improvements.[12] A study of product flow and processing time within this manufacturing system is necessary for understanding the mechanisms for improving production rate. It will become evident that the project being completed here is targeting productivity improvements within the manufacturing system through a significant reduction in processing time at a particular stage of product flow.

2.Methodology

Finite element method (FEM) is the numerical method to obtain the approximate solution when it is difficult to obtain solution analytically. The FEM or FEA is a computational technique used to obtain approximate solutions of boundary value problems in engineering. Boundary value problems are also known as field problems. Field is the domain of interest or mostly a physical structure which are governed by field variables by the differential equations under the boundary conditions or the specified values of field variables. The computational modeling using FEM is applied to analyze the behavior of the phenomenon in a system. The five major steps for the computational modeling are:

1. Modeling of geometry
2. Meshing (discretization)
3. Specification of material properties
4. Specification of boundary, initial and loading condition
5. Post processor - Solutions

Step 1. Modeling of Geometry

Real structures, components or domains are in general very complex, and have to be reduced to a manageable geometry. Curved parts of the geometry and its boundary can be modeled using curves and curved surfaces. However it should be noted that the geometry is eventually represented by a collection of elements, and the curves and curved surfaces are approximated by piecewise straight lines or flat surfaces, if linear elements are used. The accuracy of representation of the curved parts is controlled by the number of elements used. It is obvious that with more number of elements, the representation of the curved parts by straight edges would be smoother and more accurate.

Step 2. Meshing

A key step in the finite element analysis procedure is to mesh the model. Meshing is process of breaking the model into small pieces (finite elements). The network of nodes and elements is called a mesh and meshing is done for applying FEA in the geometrical section which is CAD model of the alloy wheel. Mesh generation is a very important task of the pre-process. It can be very time consuming task to produce a more credible mesh for a complex problem, the domain has to be meshed properly into elements of specific shapes such as triangles and quadrilaterals. Information, such as element connectivity, has to be created during the meshing for use later in the formation of the FEA equations

Step 3. Specifications of Material Properties

Many engineering systems consist of more than one material. Property of material can be defined either for a group of elements or each individual element, if needed. For different phenomenon to be simulated, different sets of material properties are required. For example, Young’s Modulus and shear modulus are required for the stress analysis of solids and structures, whereas the thermal conductivity coefficient is required for a thermal analysis.

Step 4. Specification of boundary, initial and loading condition

Boundary, initial and loading conditions play a decisive role in solving the simulation. Inputting these conditions is done using pre-processors, and it is often interfaced with graphics.

Step 5. Post-processor Solutions

After applying the boundary conditions and load and running FEA computation for the output results for the sensors chosen is done and the stress by Von Mises, Total Deformation of nodes and mass is observed.

3. Analysis Process

Analysis of the material will be done by Finite Element Analysis (FEA) using ANSYS. For CAD model generation of the selected alloy wheel model ANSYS workbench is opened, the new file is created from the menu bar and steps followed for modeling and analysis is given.

- Select the ANSYS WORKBENCH
- Create the New Material – Select the new material properties
- Sketch the Geometry on the basis of Analytical Values
- Open the Model—Select the geometry---Select the material ---Meshing
- Apply the Boundary Condition (Fixed Support)---Apply the Pressure on the Inside of wheel geometry
- Analysis—Stress & Deformation
- Validate the value of Stress From ANSYS to the Analytical

After validation optimization of the input parameters has also been performed using ANSYS applying topological optimization.

4. Results and Discussions

Although it is very hard to say what the results could be after Modelling and Optimization of Aluminium alloy wheel, since every analysis involves different cases to meet, but in general it is known that Modelling and Optimization becomes very useful and helpful for the organization once implemented successfully.

The expected results then would be an increase in the value of Applications after implementing Modelling and Optimization. Better availability, performance rate and quality rate is all possible. Better coordination among the operators of the Automobiles, better coordination of upper management and its employees.

Better design conditions could be developed, all the different benefits may occur, but of course it is not possible to list every single benefit of Modelling and Optimization of Aluminium alloy wheel to taken for granted, depends on the working environment of the organization,

Also, looking at the research works in the field of Modelling and Optimization of alloy wheel, it will be a fair guess to say that, chances of Modelling and Optimization benefiting the organization is quite guaranteed.

5.Conclusion

In the optimization of wheel rim, the wheel structure and its features are divided into two parts, namely design space and non design space. The design space is the region for optimizing the weight and shape of the arms. The wheel design space is optimized in order to withstand the existing load of the vehicle with the factor of safety with a least quantity of material and manufacturing cost and losses. The finite element analyses for the load and design analysis of an automotive aluminum-alloy wheel will be performed in this study.

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