FLEXIBLE ROBOTIC LINE FOR THE PROCESSING OF CAR RIMS AND PRODUCT IMPROVEMENT USING FINITE ELEMENT SIMULATION

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ABSTRACT: This paper is about the manufacturing process of a rim from aluminum alloy after the molding process. We describe the deburring process with laser cutting machine, surface finishing with vibration and establish the critical points on an eventual impact on a car rim. The wheel impact test evaluates the wheel structural performance for a typical impact event occurring in passenger cars. The basic design of the study is built upon the development and model optimization of car rims. This impact test performance is critical to meeting overall structural performance for the wheel. Discoveries found as a result of our analysis is the improved method which closely captures the behavior of the wheel during and after impact and the designing of wheel geometry which enhances the stability of a car in case of an accident. The paper is presenting the optimal design for car wheels. The final goal of this research is to have safer cars to drive and to create a wheel that is strong enough to resist to major deformations in case of a frontal impact at a high force.
KEYWORDS: automotive, wheel, rim, impact, test

1. INTRODUCTION

The use of mechanical parts manufactured with aluminum alloy have increased in the automotive industry due to its high strength and weight ratio, low cost, and innovative designs. In recent years, the market for aluminum wheels has grown considerably for transport vehicles. In the design departments, the geometry of the wheel is constantly improved and must meet certain design criteria, related to its shape, weight and manufacture process in order to guarantee safety, [1,2]. It is necessary to consider that the wheels support static and dynamic loads present during the operation of the vehicle, [3,4]. Thus, the design of the wheel is constrained by performance parameters related to its strength and functionality. The automotive industry is in permanent search of ways to reduce manufacturing times and the number of tests for product deployment. To increase productivity, we have turned to unconventional processing technologies. The design process can be improved through the use of computer-assisted engineering.

2. DEBURRING USING THE LASER CUTTING PROCESS

Actually, the deburring process will be done with classical CNC milling machines or using robots equipped with powered milling tool. We propose to cut the feeders and the casting network by robot equipped with laser cutting head. The rim with feeders is shewed in figure 1.

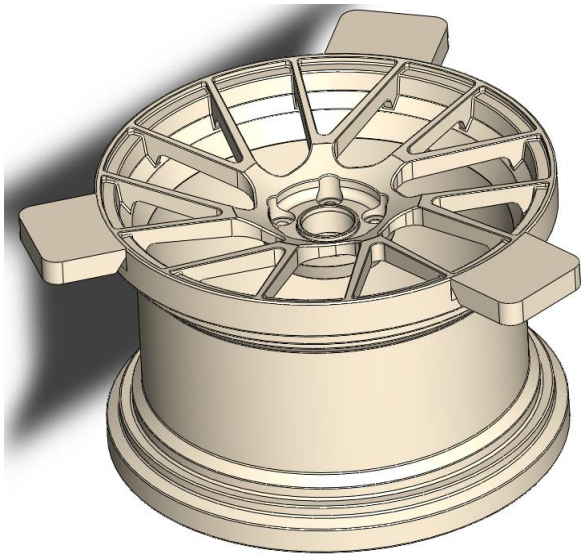

Figure 1. The rim with feeders

In this step we put the rim in an fixing device by an robot and another robot take the cutting operation with laser head.

3. SURFACE FINNISHING USING ULTRASONIC BATH

Actually, the surface finishing is done by using polishing by industrial robot equipped with powered polishing tool that follow the rim configuration.

We propose to use an ultrasonic bath for surface finishing.

An industrial robot picks up the rim from the deburring station and put it in the ultrasonic bath. After the process is done the robot pick up the rim from the ultrasonic bath and put it in the quality check station.

4. FINITE ELEMENT ANALYSIS AND FAILURE CRITERIA

Along with the fundamental tests, deformation or crushing tests may also be conducted on wheels. These tests may characterize the mechanical performance of wheels in terms of crushing and are valuable for designers to make decisions for design change. One of the less frequently applied tests on wheels is on its crash performance. In a study related to crash performance of aluminum alloy wheels, investigators focused on material and damage modelling by using real wheel samples. After characterization by conducting static and dynamic tests on wheels their study continued with the crash test applied on wheel at dynamic rate (8 m/s and 250 kg), and its simulation with SolidWorks SimulationXpress.

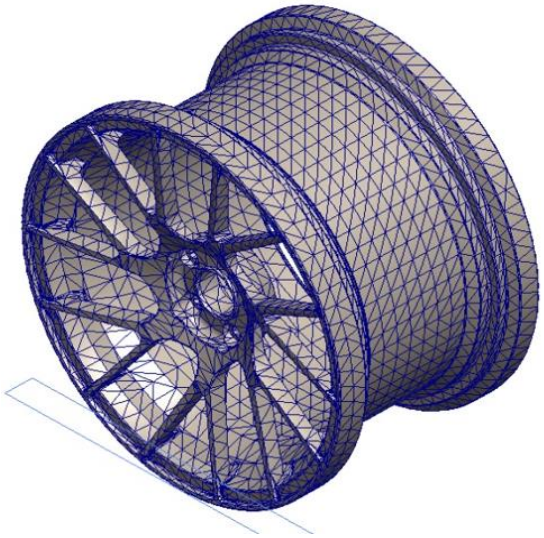

Figure 2. Generated between the central component of the support and the rim

Their study showed that a simple stress triaxiality dependence is enough to be able to obtain a representative simulation. In this study we investigated the compressive deformation and progressive failure of aluminum alloy wheels. Modeling the mechanical response of the wheel assembly is a complex task as it involves non-linear analyses, [5,6].

We use an explicit finite element formulation to consider dynamic effects and contact. There are two failure criteria established in the standard for the impact test of the wheel:

- there are no visible fractures that penetrate the central component of the tire assembly, [7]. No separation can be generated between the central component of the support and the rim, figure 2.
- it is required to maintain the pressure at a specified value during a lapse of time of one minute after performing the impact test, [8,9]. In addition, the damage or deformation in the area of the edge of the rim that is in direct contact with the face of the striker is not considered as a fracture. The wheels are visually inspected using penetrating liquids after the impact test.

4.1 Model Information

The wheels that were chosen for this project are 508mm/20inch in diameter and are suitable for personal driving cars like Mercedes GLK 350 and others. These are vehicles with mass properties of 1800 to 2000 kg, figure 3.

Boss-Extrude2			
	Solid Body	Mass:31.6956 kg Volume:0.0117391 m^3 Density:2,700 kg/m^3 Weight:310.617 N	D:\!!!! Lucru\!!! UAV\!!! 2019\Car Rim 42.SLDPRT Jun 6 22:07:19 2019

Material Properties

Model Reference	Properties	Components
	Name: 6061 Alloy Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 5.51485e+07 N/m^2 Tensile strength: 1.24084e+08 N/m^2	SolidBody 1(Boss-Extrude2)(Car Rim 42)

Figure 3. Solid Body and Material Properties

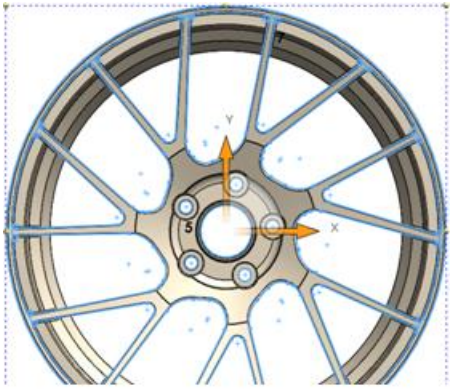

Figure 4. 3D model created with SolidWorks

The 3D model was created with SolidWorks, figure 4. First, the Boss-Extrude function for the sketch with outer ring and spokes, then a few Cut-Revolve centered at axis was used. The model has been finished by fine tuning the edges with Fillet-Chamfer.

5. FIXED GEOMETRY AND LOAD FORCE APPLIED ON IMPACT

As the chosen rim is suitable for cars with mass m=2000 kg, the load for one wheel would be 500 kg,

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	23.9328 mm
Tolerance	1.19664 mm
Mesh Quality Plot	High

Figure 5. Mesh Information

for that reason, we think it is enough in our simulation to apply a force of F=10000 N which is double the amount, to realise the static impact test,

figure 5. The fixed geometry is the surface of the central hole, where the axis would be, figure 6. The applied force of impact is highlighted in this image with purple arrows at the bottom of the rim. The contact surfaces are the two rings with the biggest diameter.

Basically, a cylinder crushing problem results in a flat-topped force-displacement curve because its so-called Type I nature. Difference occurs in this study because spokes of wheel turns the problem into crushing of Type I structure with somehow an encaser support.

This increases the stress in the outer flange region and presence of valve hole here increases the stress triaxiality ratio and becomes a weak portion and suitable for damage.

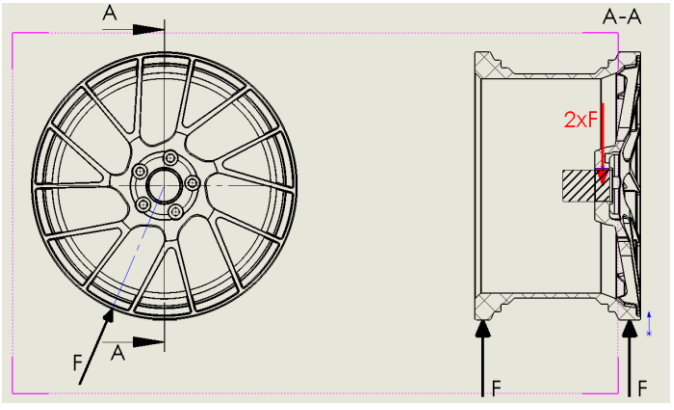

Figure 6. Static impact test

In simulation this was not observed which is most probably due to the use of critical strain approach.

In the critical strain approach, an element fails when its equivalent plastic strain reaches to a predefined critical value. But in real condition, failure strain for a ductile material mainly is dependent upon the stress state that is subjected to.

Total Nodes	41832
Total Elements	22904
Maximum Aspect Ratio	33.705
% of elements with Aspect Ratio < 3	59.9
% of elements with Aspect Ratio > 10	7.58
% of distorted elements(Jacobian)	0
Time to complete mesh:	00:00:21
Computer name:	

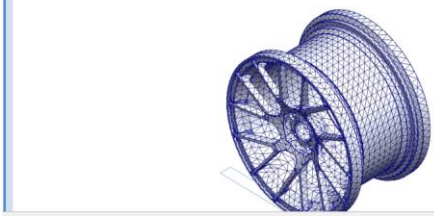

Figure 7. Total node

This stress state is defined by stress triaxiality for that loading. A stress triaxiality dependent failure model would probably be more successful to model force-displacement behaviour, because, TRIAX field variable showed high stress triaxiality for valve hole region (between 0.4-0.5).

Damage evolution behaviour for this investigation must be also calibrated.

6. STUDY RESULTS

Generally they are made of A356 (with 7% Si and 0.3% Mg as main alloying elements) casting alloy and T6 heat treatment is applied.
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Generally the wheels are made of A356 (with 7% Si and 0.3% Mg as main alloying elements) casting alloy and T6 heat treatment is applied. The red arrow on the scale in the right corner indicates the flow limit of the material, figure 8.

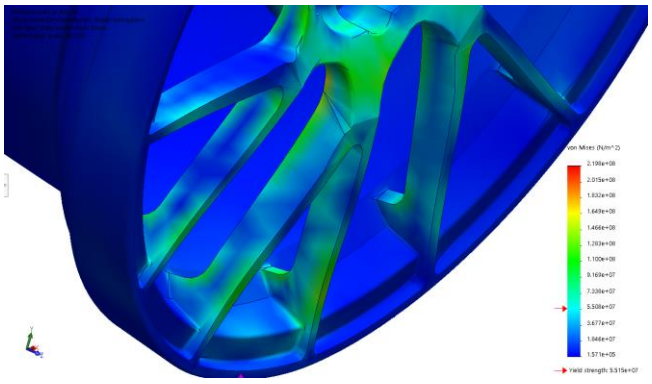

Figure 8. Flow limit of the material

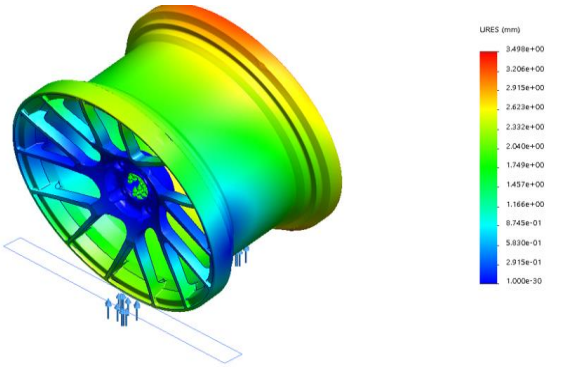

Figure 9. Rim 42 – SimulationXpress Study-Displacement-Displacement

Our analysis shows that at the selected force of impact there will be plastic deformations, highlighted with green colour on the rim. In this section we will also talk about study results for displacement. As aluminum alloy shows ductile behavior, its damage is dependent on the stress state obviously. Therefore low stress triaxiality results in higher failure strain. Due to valve hole, outer rim portion is subjected to a stress state with higher stress triaxiality resulting in failure before other regions having higher equivalent plastic strain.

In the picture below, the displacement can be seen that occurred during the impact simulation and the displacement with the highest value appear on the outer lip of the rim towards the centre of the car and the displacement value is of almost 4mm, figure 9.

In the last picture of the presentation, the simulation shows us the factor of safety.

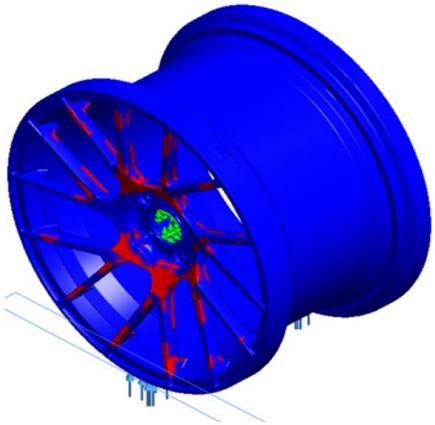

Figure 10. Highlighted with red the stress points

Highlighted with red, we can observe the stress points where the most tension is built up and those areas are the most likely to fissure or break in case of impact, figure 10.

6.1 Aluminium Wheels Examined

Variety - The wide range of aluminium wheels available make it easy to find ones suitable for your purposes, no matter what size or style you desire. They are available from a range of different manufacturers to enable you to opt for a trusted brand. There are some manufacturers who also make other car parts, which will enable you to use the same brand throughout the car.

Cost - Aluminium wheels may not be ideal if you're on a budget. The price of the wheels will vary depending on the size and style, but they are often more costly compared to steel or magnesium wheels. Different suppliers charge different sums, making it beneficial to do some research before committing to a purchase. The difference in price usually arises from the difference in the cost to manufacture the wheels.

Durability - Compared to magnesium wheels, aluminium wheels are more durable and will last longer than other materials. Aluminium wheels are stronger than magnesium wheels, with the latter being more delicate and more difficult to make. They are strong enough for use with your car without suffering significant wear and tear in the process. They come as standard on some vehicles, making them suitable for regular cars while other types are more suited to specialized cars, such as those used for racing.

Availability - There are a wide range of retailers that supply aluminium wheels, making it easy to obtain them from a convenient location. Whether you want to shop online from the comfort of your home or prefer to be able to physically examine the goods before you make a purchase, you will be able to find a retailer to suit you. This also gives you the ability shop around in order to find the best deal and the style of wheel that you want.

Combination - It is possible for the material to be combined with other substances, such as magnesium. This will create alloy wheels that take benefits from each of the materials, which will make them both strong and light.

Handling - You will find that fitted wheels made from aluminium will change the way the vehicle handles, which will mean you have to get used to the change. The handling will often be improved, the car becoming more responsive on operation of the brake and accelerator. In addition, they are beneficial at ensuring that your tires retain their shape rather than bulging out. This can help to reduce the possibility of accidents due to the treads being able to grip the surface properly.

6.2 Magnesium Wheels Examined

Magnesium wheels certainly add a "wow" factor to a vehicle. That, of course, is the main reason people spend their money on magnesium alloy wheels. Are

looks the only advantage they possess over steel or aluminium rims consider the pros and cons of magnesium wheels before parting with your money.

Weight - Magnesium wheels are light wheels, much lighter than steel or aluminium wheels. That means they will give better mileage for your car because there's less weight to move. You'll also find that they're less prone to bend or buckle if you dip into a pot hole. This lighter weight requires less wheel balancing over the life of the magnesium wheels. It also translates into more responsive steering and handling, both of which are important factors in their favour. They corner very well with low profile tires.

On the downside, once your magnesium wheels do bend, they can't be straightened again. Because of this you have to be more thoughtful when you drive. The magnesium alloy might be durable but it does have its limits, and if you don't pay proper attention to the road you could lose your investment.

Heat - There's less overheating with magnesium wheels because they spread the heat from the brakes much more efficiently than aluminium wheels. You're less like to suffer from brakes overheating, a problem that could affect the brake pads and other parts in the braking system.

Looks - The biggest advantage that magnesium wheels offer is in the look of your vehicle. They're aftermarket wheels so they give you the chance to customize the vehicle and make it stand out from the crowd. You do need wheels that will fit your vehicle, and you can go one step further by buying chrome or colored valve caps.

The fact that magnesium wheels look so good makes them desirable to others, too. That means you'll need to use a locking nut on each wheel to prevent them being stolen.

Price - The main factor weighing against magnesium wheels is the price. They're expensive. Although magnesium wheels do confer some benefits beyond looks, those are relatively minor and not necessarily worth the price you pay.

Spending more is your decision, and magnesium wheels will have a great impact on the appearance of a car. The amount of difference they make beyond that is going to be fairly small and you need to decide if that's worth what you'll be spending.

7. CONCLUSIONS

Using laser cutting operation instead of classic milling operation create some economic advantages, if we have a mass production. We don’t need expensive solid carbide end mills; investment of laser head is amortized in about one year. One feeder is catted by laser in 2 sec, using the milling process, we cut it in 8 - 10 sec.

If we use the ultrasonic bath instead of polishing process, we can reduce the process time for this operation because we working on all surfaces at the same time. There are many surfaces where the felt disc don’t have access.

After taking notice of this static simulation and the damage it can do to a rim, it is our strong opinion we should always check for the optimum pressure in our tires, especially when preparing for a long road.

In case of a wheel bump, never drive with a damaged wheel because the plastic deformations of the rim can lead to deformation in the axis or other essential parts of the car which rise the risk of accidents. Environmental performance of wheels is also a critical aspect considering their service life.

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