VOL. 12, NO. 22, NOVEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

DESIGN, ANALYSIS AND IMPACT BEHAVIOUR OF MAGNESIUM ALLOYS (ZK60A) OF LOW PRESSURE DIE CASTING FOR AUTOMOTIVE WHEELS BY FINITE ELEMENT METHOD

G. Ragul[1], C. V Reddy[2], V. Jaya Kumar[3], Abhijit Roy[1], Abhishek Samanta[1] and C. Sreejith[4]
[1]Department of Mechanical Engineering, Budge Institute of Technology, Kolkata, India
[2]Budge Institute of Technology, Kolkata, India
[3]Department of Mechanical Engineering, Saveetha School of Engineering, Saveetha University, Chennai, India
[4]Department of Automobile Engineering, Nehru College of Engineering and Research Centre, Thrissur, India
E-Mail: ragulme90@gmail.com

ABSTRACT

This paper presents the design, analysis and impact behaviour of magnesium alloy automotive wheels by finite element method. A new combination of alloy materials is attempted to improve the quality and service life of the wheel rim with less fatigue and reduced cost. Magnesium alloy (Zk60A) combination is selected for this work and wheel rim is designed using the Solidworks modelling software. The structural analysis of wheel rim is carried out using ANSYS software and the results are compared with that of the steel alloy. It is found that the Zk60A magnesium alloy results in lighter wheel and enjoys associated benefits like reduced stress, better mileage, improved service life, etc. With this encouraging result, the Zk60A magnesium alloy wheel will provide a better alternate to the existing materials.

Keywords: wheel rim, aluminum alloy, magnesium alloy, material reduction, finite element method, solid works and ansys.

1. INTRODUCTION

In this investigation author has done the literature review in the various combination of the materials and also compared the results. Jufu Jiang, Ying Wang and Gang Chen [1] investigated the motorcycle wheel's complex shape can be achieved by the high-speed filing in the injection procedure and the mechanical properties of the parts were greatly improved due to the forging pressure. Jufu Jiang, Ying Wang and Yunfa Li *et al* [2] results that complete filling could be achieved by injection system of double control forming device and high tensile strength of 241 MPa and elongation of 13.9 % were achieved.Mattia merlin, Giuljo Timelli and Franco Bonollo *et al*, [3] Introduced the concept of Numerical simulations have been performed to study the filling and solidification Behaviour of the alloy of the wheels analyzed in order to predict the final microstructure and shrinkage formation. B. Zhang, D.M. Maijer, S.L. Cockcroft *et al*, [4] A mathematical model of the low-pressure die casting process for the production of A356 aluminum alloy wheels has been developed to predict the evolution of temperature within the wheel and die under the auspices of a collaborative research agreement between researchers at the University of British Columbia and a North American wheel casting facility.D.M. Maijer, W.S. Owen and R.A. Velter *et al*, [5] Model-based predictive control (MPC), has been developed for a low-pressure die casting (LPDC) process used to manufacture aluminum alloy wheels. The control solution was developed offline using a high-fidelity 3D finite element model as a virtual process on which open and closed loop trials were performed. A. E. Miller, D.M. Maijer *et al,* [6] Laboratory erosive-corrosive wear experiments were performed by immersing and rotating test pins in liquid aluminum A356 under different test conditions. In addition to round cross-section pins, profiled cross-section pins were used to study the influence of flow on wear behaviour.Qiang Wang, Zhi-min Zhang and Xing Zhang *et al*, [7]Extrusion from hollow billet was proposed in order to enhance the strength of spoke portion and reduce the maximum forming load. By means of the developed technique, the one-piece Mg wheels were produced successfully by extrusion from AZ80+ alloy.Ping-Li Mao, Chang-Yi Wang and Jin Sun *et al*, [8] introduced the concept of the die casting technological parameters of the magnesium steering wheel have been optimized with the aid of flow-3D software. The tensile testing results of the different part of magnesium steering wheel show that the ultimate tensile strength and elongation in the wheel arm and wheel rim have no difference and the average value are 220 MPa and 5%, respectively. The fracture is in the brittleness mode and the fatigue crack initiates at the outside of the wheel rim. [9-14] introduced the various concept of increase the tensile strength and also elongation properties of the materials."By virtue of these lighter wheels, forged wheels are at least 20% lighter, sustaining equal loads with better characteristics, which is always easier on the car and its suspension. Lighter wheels also yield shorter breaking distance, which saves lives, shorter acceleration and reduces fuel consumption."

2. STUDY ON MATERIAL REDUCTION

In order to find the relation between material reduction and mileage we used the data's in the consumer report. It provides curb weight in kilogram and mileage in km/lit Curb weight is the base weight of the vehicle i.e., the weight of the vehicle without any external load.

Fuel economy is, of course, affected by many design factors besides curb weight. Some factors that can be examined are engine HP, transmission characteristics and aerodynamic design. Not all of these can be evaluated quantitatively. However, my study shows that as curb

VOL. 12, NO. 22, NOVEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

weight increases, fuel economy of the vehicle decreases. The graph of weight versus mileage shows a nice downward trend. There is much less scatter and I can develop a simple linear regression equation (using classical least squares fitting) relating curb weight to mileage.

However, considering the difficulties in testing and the large variations in engine, transmission and aerodynamic characteristics between vehicles, it is decided to use a simpler method, and simply connected the extreme points by a straight line. The data point can then be shown to fall between the parallels with the equation y = mx + c where the constants m is the slope and c is y-intercept. We did an analysis with vehicle weight and fuel economy from the data obtained from the consumer report. Let us consider 10 different suv's from different manufacturers. The raw data is shown in Table-1.

Table-1. Curb weight and mileage.

Name	Curb weight(kg)	Mileage (km/l)
Santa fe	1920	14.66
Nissan x-trail	1618	15.1
Skoda yeti	1543	17.67
Ford endeavour	2014	12.22
Xuv 500	1865	15.1
Safari	2040	13.2
Aria	2220	14.5
Scorpio	1850	14

Depend upon the various manufacturer wheel rim can be designed as one piece, two piece, three piece rim by the forging method and also by casting method. By this different method mechanical properties also varies and also service life of the material also varied.

3. STUDY OF CURB WEIGHT REDUCTION IN DIFFERENT AUTOMOTIVES

Figure-1 presents the comparison of mileage with the weight. From the graph using the straight line equation we can deduce y=-0.01123x+25. The slope is negative which means fuel economy decreases as curb weight increases. The reciprocal of the slope has the units of kilogram per km/lit and is equal to 156.25. In other words, if the vehicle weight decreases by about 89.04 kg (or roughly 90kg), the fuel economy will increase by 1 kmpl. The intercept c = 25 also has a special significance and represents the highest mpg conceivable if vehicle weight goes x goes to zero. In other words, to develop vehicles with fuel economies significantly greater than 25kmpl.

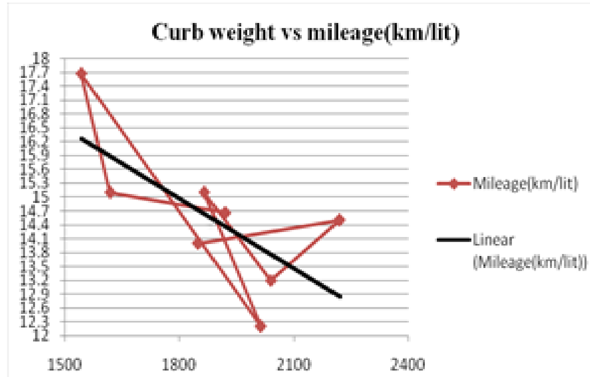

Figure-1. Comparison of mileage vs curb weight.

And also analyzed the data for vehicles produced by a single manufacturer, e.g. Toyota. The data for 6 different vehicles were chosen from this list (Table-2). The comparison of curb weights and mileages of different models are given in Figures 2 and 3 respectively.

Table-2. Comparison ofcurb weight and mileage.

Name	Curb weight(kg)	Mileage (km/l)
Fortuner	1955	14.66
Innova	1640	14.44
Qualis	1570	14
Prado	1900	11
Prius	1390	20.4
Land cruiser	2720	8

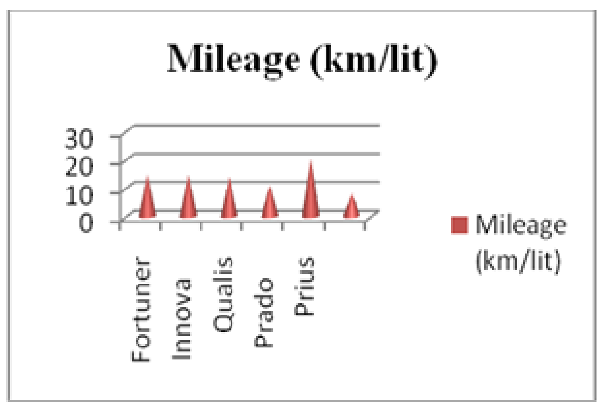

Figure-2. Comparison of mileage in vehicle.

VOL. 12, NO. 22, NOVEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

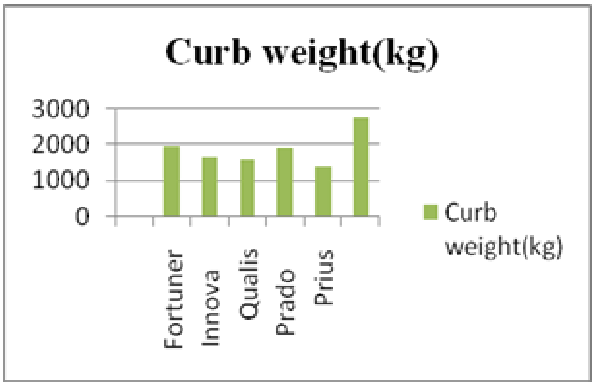

Figure-3. Comparison of curb weight in vehicle.

Figure-4 presents the comparison of mileage with the weight. The x-y graph again reveals a nice downward trend with significant scatter. We can deduce the following linear regression equation y = -0.02136x+82. The slope h = -0.02136 is higher and implies that for this manufacturer (Toyota), every 46kg reduction in vehicle weight will yield an improvement in fuel economy of 1kmpl. The intercept c = 51.03 is also higher. The conclusion is that every 100kg reduction in weight will yield a fuel economy improvement of 2.17kmpl and the theoretical highest possible mpg is about 82 mpg, if we focus only on weight reduction.

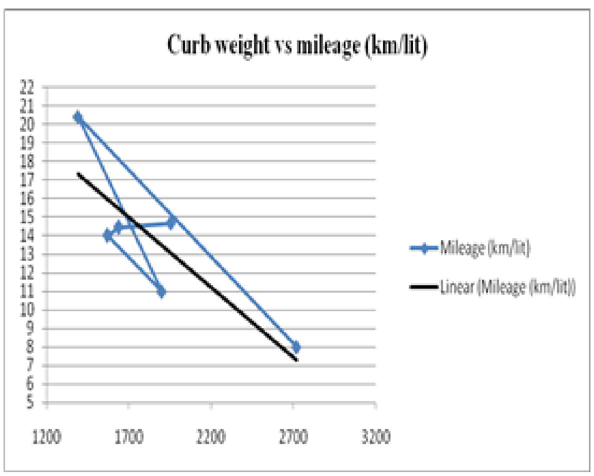

Figure-4. Comparison of mileage vs curb weight.

4. ROLE OF MAGNESIUM IN MATERIAL REDUCTION

Let us assume that 100kg of steel components with density of 7800kg/m^{3}are replaced by magnesium, the volume occupied is found as 12.82×10^{-3}m^3. For the same volume, the required mass of magnesium components with density of 1800kg/m^{3}is calculated as 23.07 kg. Thus the thumb rule based on the data is 100kg of steel equals nearly 23kg of magnesium.

5. MODELING OF WHEEL RIM BY SOLIDWORKS

Initially the 2D drawing of wheel rim is done by using SOLID WORKS according to dimensions specified in Table-3 and Figure-5. 2D drawing of wheel and wheel rim are drawn and presented in Figures 5 and 6 respectively. 3D and cut sectional drawing of wheel rim are shown in figures 7 and 8 respectively.

Table-3. Dimensions of wheel rim.

S. No	Diameter	Dimensions (mm)
1	Outer	450
2	Hub hole	150
3	Bolt hole	20
4	Rim width	254

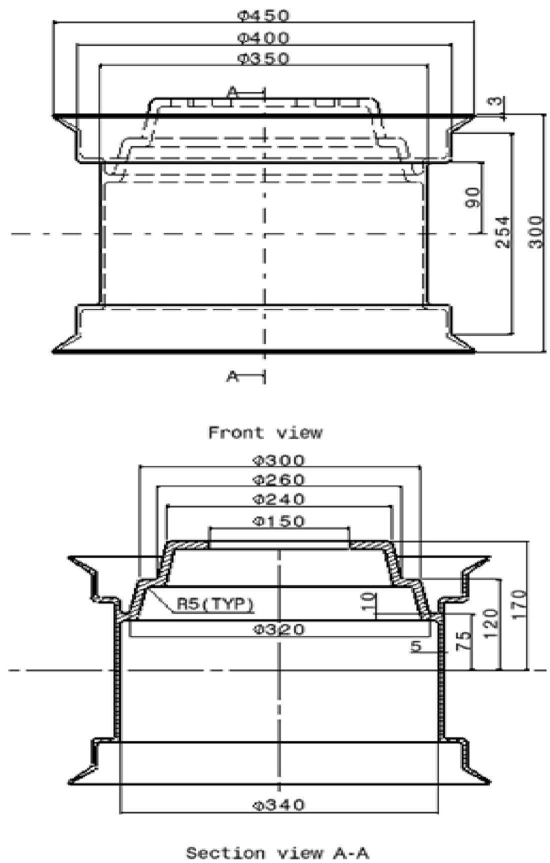

Figure-5. 2D dimensions of wheel.

VOL. 12, NO. 22, NOVEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

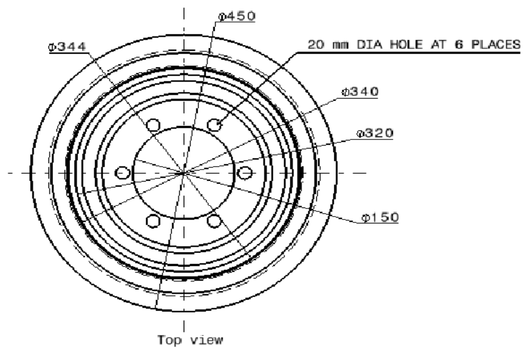

Figure-6. 2D drawing of wheel rim.

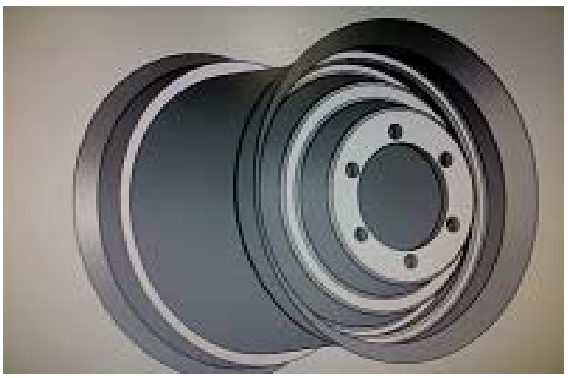

Figure-7. 3D model of wheel rim.

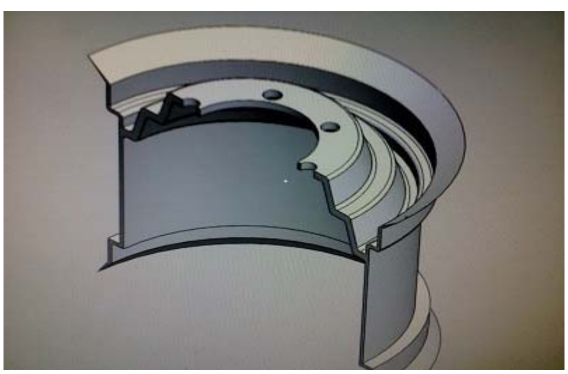

Figure-8. Cut sectional view.

6. RESULTS AND DISCUSSIONS

Figures 9 and 10 depict the ANSYS diagrams of deformation on steel alloy and magnesium alloy of wheels respectively. It is found that total deformation on steel alloy wheel rim as 0.166 mm and that of the magnesium alloy wheel rim as 0.21 mm.

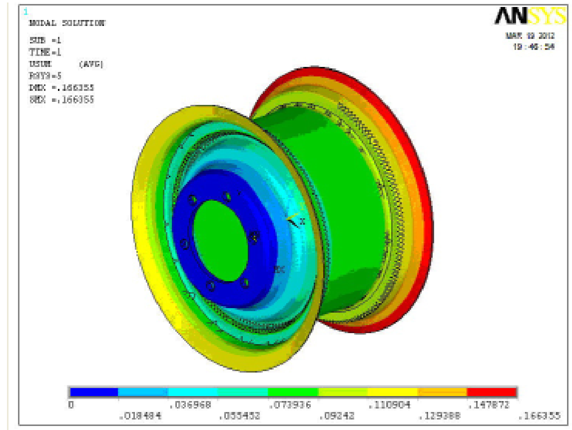

Figure-9. Deformation on steel alloy wheel rim.

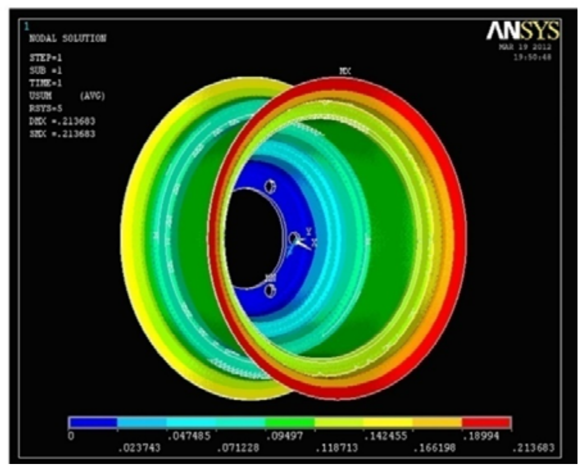

Figure-10. Deformation on magnesium alloy wheel rim.

Figures 9 and 10 depict the ANSYS diagrams of distribution of vonmises stress on steel alloy and magnesium alloy of wheel rim respectively. It is observed that the maximum and minimum vonmises stresses on steel alloy wheel rim are 142.056 MPa and 3.202 MPa respectively. On magnesium alloy wheel rim, the maximum and minimum vonmises stresses obtained are 32.294 MPa and 0.6954 MPa respectively. With this encouraging results, the Zk60A magnesium alloy wheel provides a better alternate to the existing steel alloy materials.

ARPN Journal of Engineering and Applied Sciences

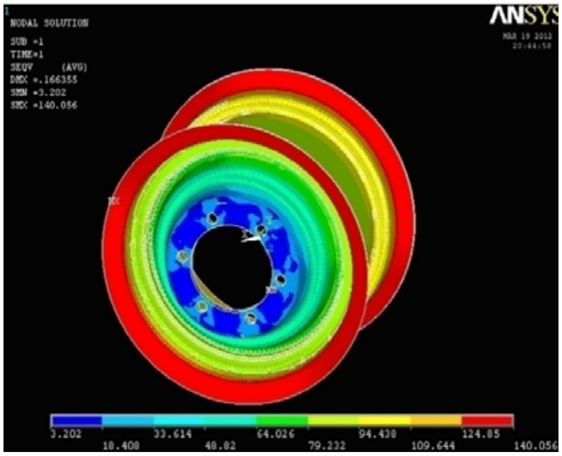

Figure-11. Stress on steel alloy wheel rim.

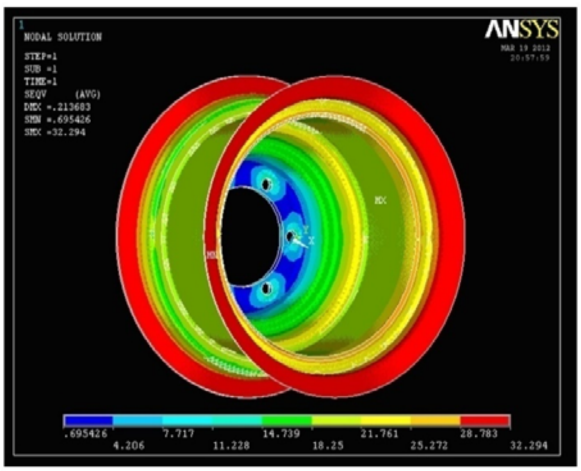

Figure-12. Stress on magnesium alloy wheel rim.

7. CONCLUSIONS

In this work, the design, analysis and impact behaviour of magnesium alloy automotive wheels by finite element method is presented. The main findings of this analysis include: (i) Stress developed in the steel alloy is 142.056MPa which is below the yield stress of the material; (ii) Stress developed in the magnesium alloy is 32.294MPa which is below the yield stress of the material; and (iii) Comparatively stress developed in the magnesium alloy is lower than the stress developed in steel alloy. It is found that the Zk60A magnesium alloy results in lighter wheel and enjoys associated benefits like reduced stress, better mileage, improved service life, etc. With this encouraging result, the Zk60A magnesium alloy wheel will provide a better alternate to the existing materials. Besides by using magnesium alloy the unsprung mass of the vehicle is reduced which improves the vehicle performance.

REFERENCES

[1] Jufu Jiang, Ying Wang, Gang Chen and Yunfa Li *et al*. 2012. Comparison of mechanical properties microstructure of AZ91D alloy motorcycle wheels formed by die casting and double control forming. Materials and Design, Elsevier. 40: 541-549.

[2] Jufu Jiang, Ying Wang and Yunfa Li *et al.* 2012. Microstructure and mechanical properties of the motorcycle cylinder body of AM60B magnesium alloy formed by combining die casting and forging. Materials and Design, Elsevier. 37: 202-210.

[3] Mattia merlin, GiuljoTimelli and Franco Bonollo *et al.* 2009. Impact behaviour of A356 alloy for low-pressure die casting automotive wheels. Journal of Materials processing Technology, Elsevier. 209(2): 1060-1073.

[4] B. Zhang, D.M. Maijer, S.L. Cockcroft *et al*. 2007. Development of a 3-D thermal model of the low-pressure die-cast (LPDC) process of A356 aluminum alloys wheels", Materials science and Engineering: A, Elsevier,Vol 464, Issue.1-2, Pp. 295-305, Aug 2007.

[5] D.M. Maijer, W.S. Owen and R.A. Velter *et al*. 2009. An investigation of predictive control for aluminum wheel casting via a virtual process model. Materials science and Engineering: A, Elsevier. 209(4): 1965-1979.

[6] A.E.Miller, D.M. Maijer *et al.* 2006. Investigation of erosive-corrosive wear in the low pressure die casting of aluminum A356. Materials science and Engineering: A, Elsevier. 435-436: 100-111.

[7] Qiang Wang, Zhi-min Zhang and Xing Zhang *et al*. 2010. New extrusion process of Mg alloy automobile wheels. Transactions of Nonferrous Metals society of china, Elsevier. 20(2): 599-603.

[8] Ping-Li Mao, Chang-Yi Wang and Jin Sun *et al*. 2008. Fatigue Behaviour of magnesium alloy and application in auto steering wheel frame. Transitions of Nonferrous Metals society of china. 18(1): 218-222.

[9] Liu Jude, Men Young Xin. 1993. A modified point contact tire model for the simulation of vehicle ride quality. Journal of Terramechanics. 30(3): 133-141.

[10] S.J Nalluveetil, G. Muthuveeran. 1993. Finite modeling and analysis of a straight bevel gear tooth. Journal of Terramechanics. 48(4): 739-744.

[11] S. Ganesh g, Dr. P.Periyasamy. 2014. Design and analysis of spiral wheel rim for four wheeler. IJES. 3(4).

[12] E.G.Markow *et al.* Development of Elliptical wheel", Journal of terra mechanics. (2): 69-74.

[13] Silliman JD, editor: 1992. Cutting and Grinding Fluids: Selection and Application. Society of Manufacturing Engineers, Dearborn Michigan.

[14] D. Santhosh Kumar, V. Jayakumar and Shajin Majeed, Modal Analysis and Design Optimization of Automotive Wheel Rim. Journal of Chemical and Pharmaceutical Sciences. 10(1): 667-669.