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Plastic Ball Bearing Design Improvement Using Finite Element Method

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Abstract

Vehicle suspension systems as well as steering system include component that is called ball joint which the main characteristics is to connect vehicle component each other and move with three degrees of rotational freedom. One of the main part of the ball joint is a plastic ball bearing due to minimize wear, reduce friction. Actually, plastic ball bearing has crucial role product life cycle. The main objective of this study is to improve model and to perform structural analysis of a plastic ball bearing used in the front suspension system. Two major properties, geometry and material have investigated. Various geometrical shapes have designed and have analyzed using finite element method. Although a wide variety of plastics are available, different types of POM (polyoxymethylene) have studied. Analyses have included the evaluation of the ball bearing axial and radial clearance for excessive play which is used with ball joint. According to simulation result, optimal ball bearing has developed before prototype had been produced. Simulation technology and software tools have a significant role in the design process of automotive product development.

Key words: Plastic ball bearing, product life, finite element method

1. Introduction

The suspension control arms are mounted to the on the frame, suspension subframe or body via ball joints. Ball joints are allowed three degrees of rotational freedom and transfer longitudinal and lateral forces during service conditions of the vehicle. Characteristic of vehicle steering and handling, ball joints have some requirements. It is important that there is no excessive play within ball joints and further important that the friction between surfaces ball joint component occurs torque which is play significant role for the life of the ball joint.

Suspension and steering and ball joints consist various elements that their responsibles, geometrical shapes and materials are different. The figure 1 demonstrates a ball joint depicting its components. The ball joints main components: ball stud provide a mechanical connection between the housing and with castle nut and cotter pin. The ball stud is subject to the highest forces in the ball joint. Housing is the base component designed to accommodate the ball stud and ball bearing. Dust cover is designed for protecting the ball joint from contamination that causes additional wear on the ball bearing and corrosion of the ball stud. One of the main part of the ball joint is a plastic ball bearing due to minimize wear, reduce friction, better vibration damping.

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As a failure mode vibration, non-confirming axial and radial clearance, excessive play and as a consequence of all these defects can be notice when the ball joint is not working appropriately. Actually, plastic ball bearing has crucial role product life cycle of ball joints.

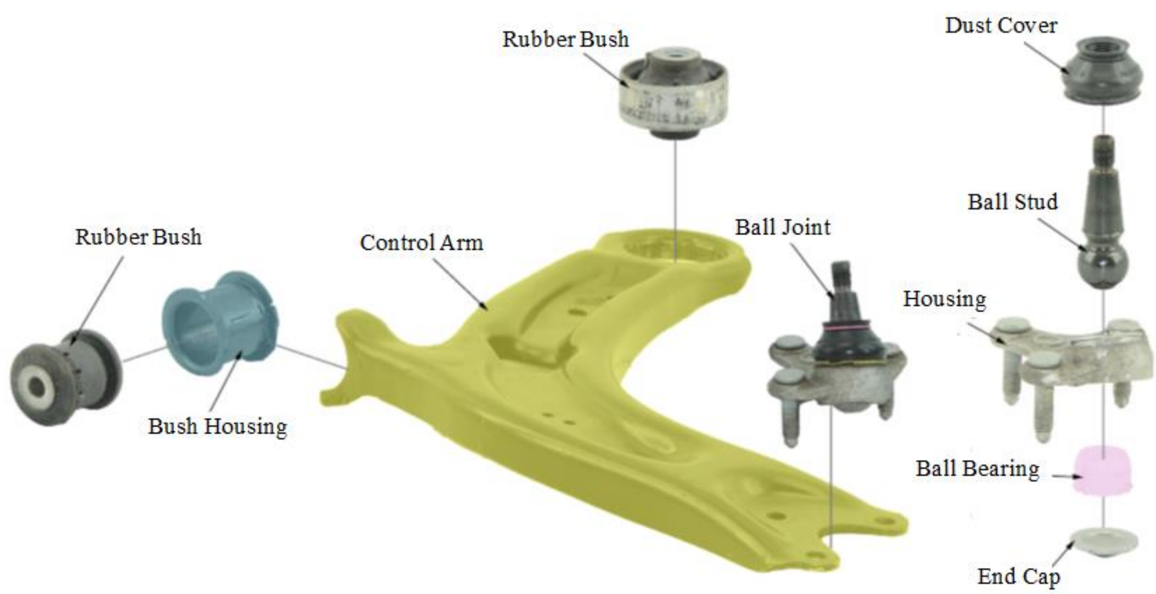

Figure 1. Suspension Ball Joint Components

One of the important parameter for product life cyles is friction that associated ball bearing contact geometry, surface pressure, ball bearing material compatibility, solid interference, the surface roughness and the thickness of the lubricant.

Ball joints bearings are made from POM (polyoxymethylene), is the standard material used for ball bearing due to its low friction and wear coefficients, high strength and good shape retention. Due to the function of the ball bearing and its material and requirements, this component generally presents a complex geometry. The figure 2 shows different types of ball bearing made of Delrin® 100 NC010.

Figure 2. Different Types of Ball Bearing

The ball bearing must possess the outstanding friction and wear properties and an allowable at operating temperature. Furthermore, bearings must have lubrication grooves that the lubricant like as grease can accumulate and float itself.

The main objective of this study is to improve model and to perform structural analysis of a plastic ball bearing used in the front suspension system. In this study two major properties, geometry and material have investigated to improve model. Various geometrical shapes have designed and have analyzed using finite element method. Although a wide variety of plastics are available, different types of POM have studied.

2. Method and Materials

Ball bearing part development process has been started with technical engineering request. Before redesign ball bearing part, to compare the used and unused part ball bearings have scanned with 3D surface scanner. Figure 3 shows the scanned parts. It was observed that used ball bearing was bulged under the service conditions. The grey one is under the service condition that has bulged cover area. It has been decided to improvement the ball bearing geometrical studies taking into account other internal effects.

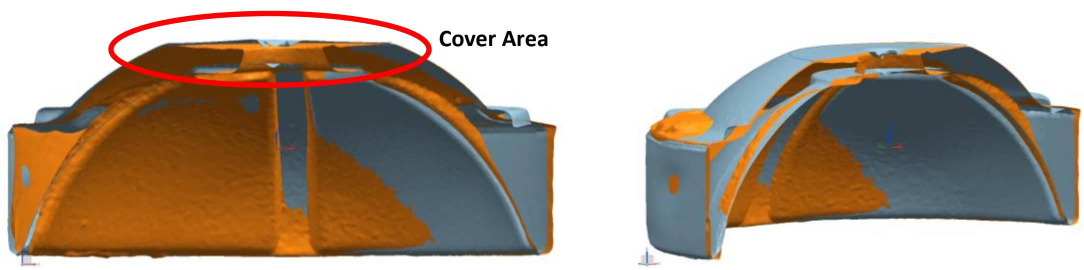

Figure 3. Scanned Ball Bearing Parts

In the first step the existing ball bearing part is prepared for redesign via 3D surface scanner. In the following existing part modified and thickened the thin-walled support (rib) throughout cover region where was bulged. Afterwards, modified ball bearing was produced that its material as same as existing parts. The existing and revised design is demonstrated in Fig. 4

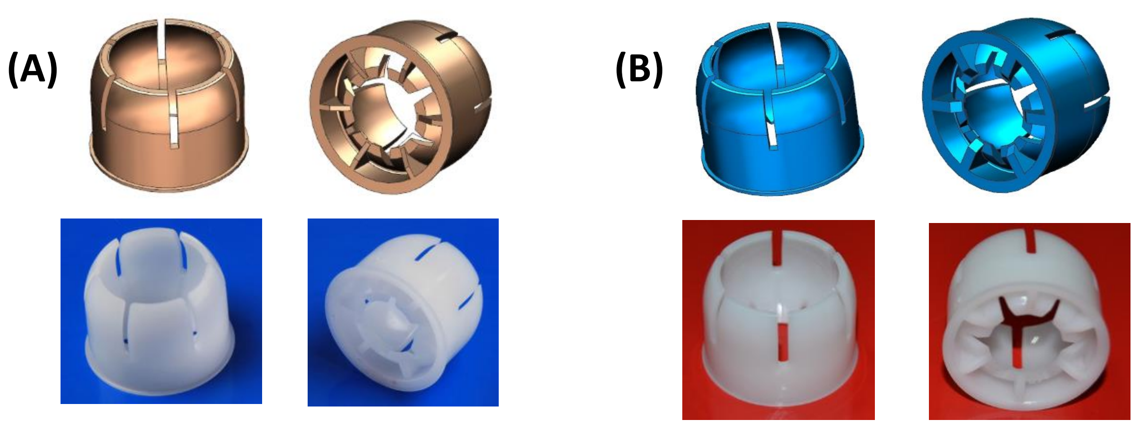

Figure 4. The Existing Desing (A) & The Revised Design (B)

Revised designs have been tested experimentally. According to ball joint life test, axial and radial clearance test part has been rejected. Test ring and result presented in Fig. 5.

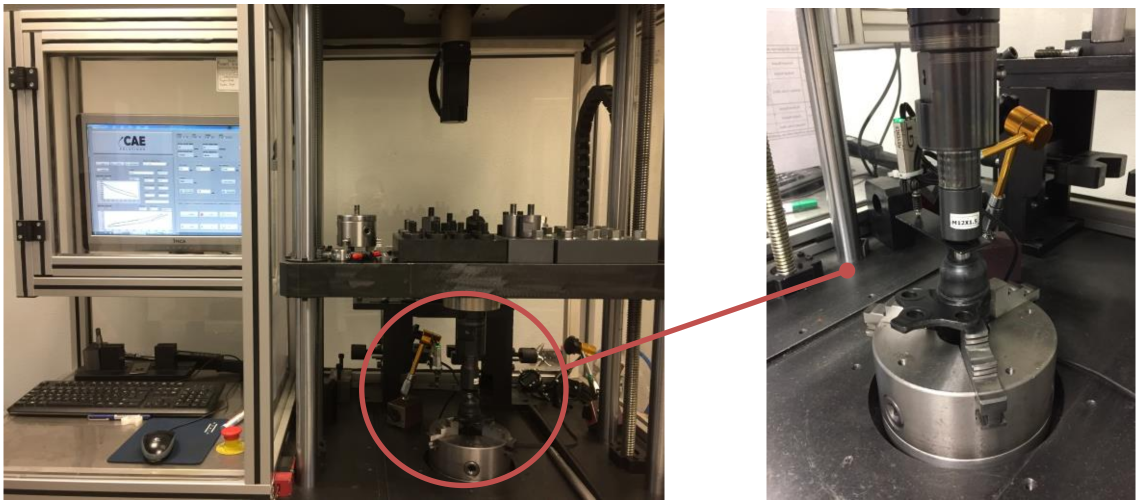

Figure 5. Ball Joint Test Ring and Result

Improvement studies has begun again to reinforce the modified design because the test results are not in line with the engineering technical specifications. In these studies, improvement modelling has started with finite element simulations. According to specified load and boundary conditions, ball bearing has examined. Finite element result show that the cover region where ball bearing bulged must have reinforced. Afterwards, the results has evaluated and determined that improvement studies were done not only geometrically but also as material. In the meanwhile final design has released. Final design is slightly different from the existing ball bearing but has several characteristics feature in common. The FEM result and final design is demonstrated in Fig.5.

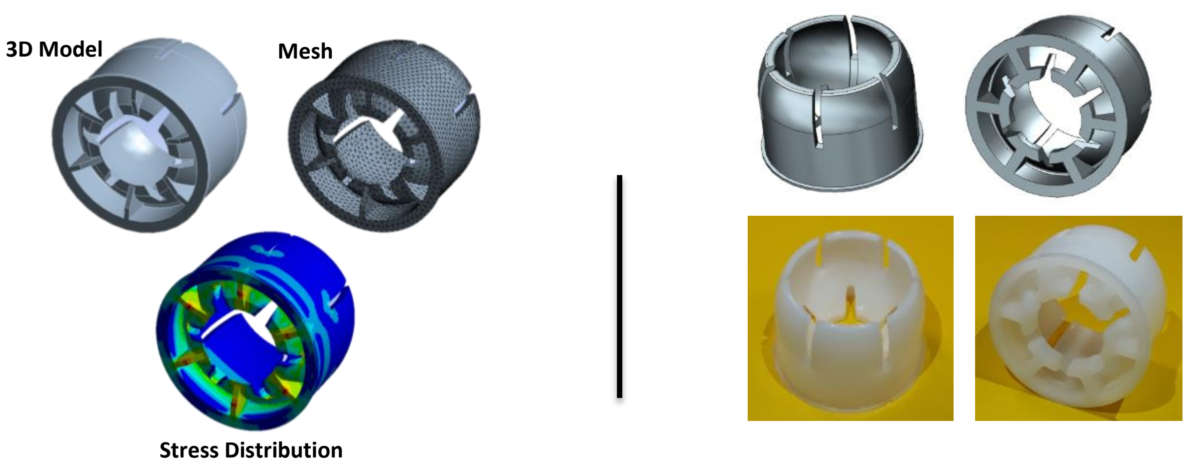

Figure 6. The FEM Result and Final Ball Bearing Design

Materials and their properties that is used for ball bearing is shown in Table 1.

Table 1. Properties of Materials

Properties	Physical	Value			Unıt
		Delrin® 100	Delrin® 300	Delrin® 7057	
Rheological	Melt volume-flow rate	1.9	12	21	$cm^3/10min$
	Melt mass-flow rate	2.3	14	25	g/10min
Mechanical	Tensile Modulus	3000	3000	3300	MPa
	Yield stress	72	66	71	MPa
	Yield strain	26	11	12	%
	Flexural Modulus	2900	2800	3000	MPa
	Compressive strength	110			MPa
	Hardness, Rockwell, M-scale	90	89		
Thermal	Melting temperature, 10°C/min	178	178	178	°C
	Coeff. of linear therm. expansion, parallel	110	120		E-6/K
	Spec. heat capacity of melt	3000			J/(kg K)
	Eff. thermal diffusivity	1,00E-07			m^2/s

Using these materials ball bearing was produced based on final design. After their assembly, ball joint tested after waiting for a while (according to technical specification) and result investigated. Rotation torque, breakaway torque, oscillation torque result and life cycle test results were performed as indicated in Table 2.

Table 2a. Test Result of Rotation Torque Initial Value

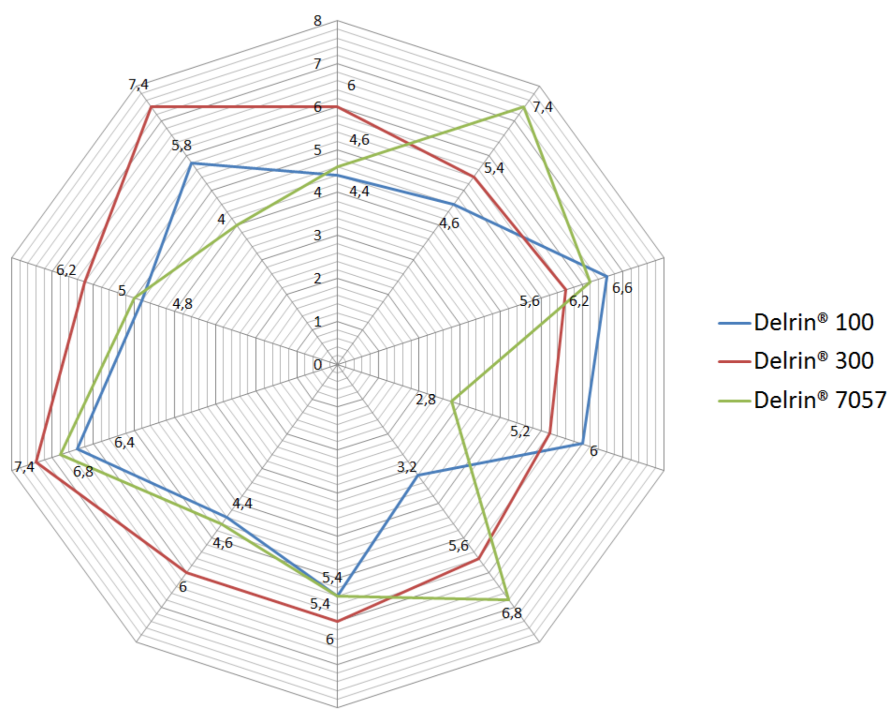

Table 2b. Test Result of Product Life Cycle

BALL JOINT DYNAMIC TESTING REPORT							
CYCLIC TEST	**Total Axial Clearence (mm)**		**Rotation Torque (Nm)**		**Breakaway Torque (Nm)**		**Explanations**
	Specification	Result	Specification	Result	Specification	Result	
Before Test	0.5 mm at ±2000N	Pull: 0.034 Push:0.043 Total: 0.077	0.5-5	1,7	0.5-1	4,3	OK
After 500000 Cycles	0.5mm at ±2000N	Pull: 0.013 Push:0.115 Total:0.128	0.5-5	0,62	0.5-1	0,53	

Conclusions

It is observed that the cover region of the ball bearing is critical for product life cycle. As a result of improvement study, the shape and material of ball bearing has been changed. Delrin® 100 was determined to be the most suitable material for the ball bearing. As a consequence of changes clearances, torque values and life cycle have increased. The final ball bearing has design line in with technical engineering specifications. In the meanwhile, seems that axial and radial clearances play significant role for the life of the ball joint. Also this study shows that virtual analysis methods' results leads us how to design and modify ball bearing before physical prototype phase.

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