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Modelling and Static Analysis of Wheel Spacer

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***Abstract*— This paper focused on modelling and analysis of a wheel spacer in automobiles. Wheel spacers are used to improve stability, handling and also to provide better safety in automobiles. Wheel spacers help in moving the wheel out of the hub, thus widens the vehicle stance and lowers its roll center. Depending on vehicle make and model, they are available for most domestic and imported automobiles.**

The wheel spacer is modelled in SOLID EDGE ST4. The designed model is then imported to ANSYS 15.0 Workbench and further analysis is completed under different loading conditions. Finally the whole results are validated.

***Index Terms*— Spacer, roll center.**

I. INTRODUCTION

The wheel is one of the main components in the vehicle design. A wheel is a circular shaped component that rotates on an axle bearing. Wheels in relation with axles, allow heavy objects to be moved easily facilitating transportation while supporting a load, or performing labour in machines. Wheels are also used as flywheel, ship's wheel, steering wheel, and potter's wheel.

The wheel spacers are one of the important part in automobiles. They offer the option to widen the wheelbase of your vehicle. The usage of wheel spacers can change the clearance on cars, the way it handles, or just make the car look more aggressive. The car looks sportier when wheels stick out farther from the vehicle. Wheel spacers not only change the look of a car, but also widens the distance between tires that helps in increases handling in curves. But installing wheel spacers will affect other vehicle components which can lead to quicker wear in some cases.

II. WHY WE USE WHEEL SPACERS ?

A. Wheel Track Width

Wheel track width is an essential parameter in vehicle design. Widening wheel track will improve grip and can handle by simply pushing out the wheels. This enables the car to be more stable and predictable when pushed at its limit. This is similar to buying a wider rim, without the true cost of another rim, tire and labor.

B. Clearance

The next use of wheel spacers is for obtaining sufficient clearance. The spacers must be modelled depending on the style of rim and offset. Most big brake kits require a 17inch rim or larger and even then the design or mounting surface of the rim itself may become problematic. In this context, we need a spacer to give brakes and rims the clearance they need. Without the use of a spacer, the wheel may strike or scrape the big brake kit, will result in further problems.

C. Wheel Out-Look

The usage of spacer will change the overall out-look of the vehicle. Rims and tires that fully take up the wheel will coincide with the fender line, giving an aggressive and stylish look.

D. Adjusting Offset

Another usage for wheel spacers is the offset. If the rim’s offset is too high, the wheels will sit too far inward and maybe even ruin the inside fender liner when making U-turns. This condition also leads to hitting suspension components like control arms and coil-overs. Correct this issue by installing the correct wheel spacers to push the wheels outward and restoring the look and ride of vehicles.

III. PROS AND CONS OF WHEEL SPACERS

A. Pros of Wheel Spacer

- The vehicle appear more aggressive, since effective offset of wheel is lowering the tire setup.
- Wheel spacers will increase the track width, provides more control over the automobile.
- Thus provide better stability also.

B. Cons of Wheel Spacer

- Usage of excessively wide wheel spacers and rims will negatively affect the wheel bearing’s life.
- Usage of wheel spacers will leads to increase of load on the wheel bearings, wheel retaining bolts, steering gear as well as suspension components.
- This will change the airflow over the brakes, and will rub the wheel arches under certain steering angle/suspension movement combinations.

Spacers like every material can be classified as good and bad ones. Bad spacers are metal plate pressed having huge multi fitment holes in them whereas the good spacers which are known as "hub-centric" which are machined specifically from solid material for a particular fitment. The bad ones will cause tramlining, wheel bearing wear, bump steer, arch clearance problems etc. They will also ruin steering

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geometry, and thus reduce the thread engagement of the wheel nuts dangerously sometimes. Also they can impose a higher load on the wheel bearings leads to reduction of life.

IV. HOW WHEEL SPACERS AFFECT WEAR OF OTHER COMPONENTS?

Generally, the wheel bearings experience greater force. Along with that, the forces which affect the axle will also tends to increase the load on bearings. The large amount of leverage places will cause extra strain on the wheel bearings. This leads to increase of pressure on individual components, including shocks, rubber bushings, etc.

Leverage change wears tires more quickly especially the interior side. Wear is independent on the width of tire, the dimensions of wheel spacers, or the quality of the tire. If wheel spacers are added to the front wheel of vehicle, the scrub radius will also increases and steering will feel heavier.

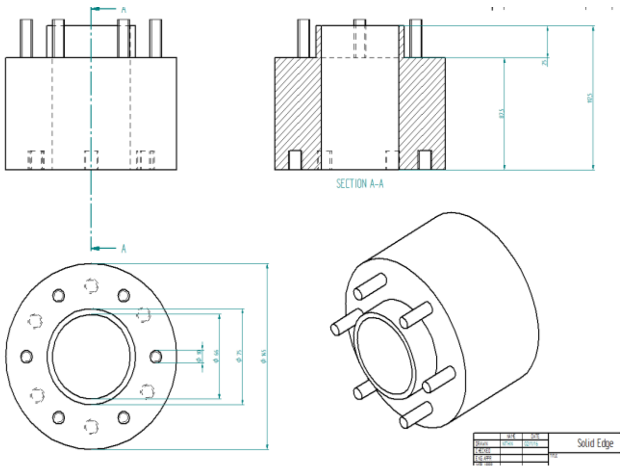

Fig 1 a: Modelled wheel spacer

V. MODELLING OF WHEEL SPACER

The initial step is to model a wheel spacer. The necessary dimensions are taken from work done by Dr. Suwarna Torgal and Swati Mishra [6]. They conducted a study on stress analysis of wheel rim and put forward a design of wheel rim which can transmit a torque of 2070 Nm. Based on that, a wheel spacer is modelled. The modelling is performed on Solid Edge ST4.

TABLE I DIMENSIONS OF MODEL

FEATURE	VALUE
Inner Radius	66 mm
Outer Radius	145 mm
Length	112.5 mm

VI. RESULT AND DISCUSSION

A. *Static Analysis*

The developed geometric model has been meshed and the subsequent static structural analysis has been carried out using ANSYS WORKBENCH 15. Under steady state operating conditions, the wheel spacer geometry is treated as a composite cylinder subjected to transverse load, torque and angular velocity; these values are provided in Table I.

The transverse geometry is fixed at rear portion (in stud holes) of spacer and conditions are provided. Since the geometry lies in Y-Z plane, load is provided on negative Z direction, torque and angular velocity acting along Y axis. Mesh optimization is done based on these conditions.

TABLE II LOAD CONDITIONS ON WHEEL SPACER

PARAMETER	VALUE
Force	5000 N
Moment	2070.02 Nm
Angular Velocity	23.27 rad/s

As first part of the static structural analysis, wheel spacer mesh convergence study has been conducted and then the optimized mesh size has been determined. Then the modelled wheel spacer's static structural stress analysis has been conducted to determine the safety of the given structure.

B. *Mesh Optimization*

Mesh convergence study of wheel spacer has been performed. The spacer has been fixed at bolt holes and treated as a shaft subjected to a force, moment and angular velocity whose magnitudes are as that mentioned on Table I. The geometry lies on Y-Z plane. The spacer geometry has been meshed with 9155 nodes and 4071 elements using triangular mesh in the beginning and then it is subjected to static structural analysis. The parameters analyzed are maximum deformation, equivalent strain, equivalent (Von-Mises) stress, maximum and minimum principal stress, maximum shear stress and F.O.S. Then the number of nodes and elements has been varied up to 15971 elements and 31734 nodes. The corresponding results have been shown on Tables.

TABLE III DATA RELATED TO DIFFERENT TYPES OF MESH

TYPE OF MESH	EQUIVALENT STRAIN		EQUIVALENT STRESS		MAX. SHEAR STRESS	
	MAX	MIN	MAX	MIN	MAX	MIN
FINE 31734 nodes 15971 elements	0.00020493	2.141 x 10^{-10}	3.0001 x 10^{7}	41.651	1.7271 x 10^{7}	23.914
MEDIUM 18971 nodes 9658 elements	0.00020361	4.2258 x 10^{-10}	3.0526 x 10^{7}	39.733	1.712 x 10^{7}	22.744
COARSE 9155 nodes 4071 elements	0.00023349	3.6085 x 10^{-10}	3.2192 x 10^{7}	59.25	1.8572 x 10^{7}	33.374

TABLE IV MESH CONVERGENCE STUDY OF WHEEL SPACER

TYPE OF MESH	TOTAL DEFORMATION (m)		F.O.S
	MAX	MIN	
FINE 31734 nodes 15971 elements	5.7379 x 10^{-6}	0	8.332
MEDIUM 18971 nodes 9658 elements	5.7155 x 10^{-6}	0	8.1897
COARSE 9155 nodes 4071 elements	5.5413 x 10^{-6}	0	7.766

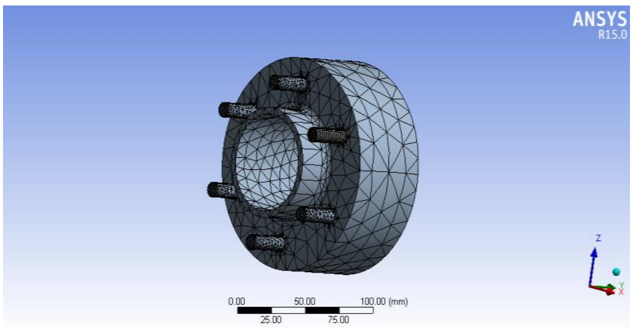

Fig 2: Meshed wheel spacer

From the data shown on Table III, it is clear that the change in the obtained values of maximum deformation, equivalent (Von-Misses) stress, equivalent strain and maximum shear stress almost same as the number of nodes has been changed from 9155 to 31734. So the mesh size with 31734 nodes has been selected as the standard mesh size (fine) for further calculations. The percentage variation of the respective parameters has been shown on Table V.

TABLE V PERCENTAGE CHANGE OF SPACER PARAMETERS

TYPE OF MESHING	% CHANGE W.R.T. FINE MESH		
	VON MISES STRESS (N/m^2)	MAX. SHEAR STRESS (N/m^2)	TOTAL DEFORMATION (m)
FINE	0	0	0
MEDIUM	1.74	0.8	0.3
COARSE	6.80	8.4	3.42

From the Table V, it was found that the percentage variation of Von-Mises stress, Maximum shear stress and total deformation of medium and coarse meshes are within the limit. Since the value obtained in fine mesh is much more accurate, it is selected for further analysis.

C. *Wheel Spacer Stress Analysis*

Fig 3 to 8 shows the spacer deformation, corresponding stress and strain distribution and the structure safety factor for the conditions mentioned on Table IV & V. The selected mesh size is the optimized spacer mesh size of 31734 nodes. The maximum values of total and directional deformation and maximum Von-Misses stress for this mesh size are shown on Table VI.

The wheel spacer for the subsequent analysis has been performed by treating spacer meshed with shell elements and the translational degrees of freedom have been arrested. The maximum deformation on the spacer occurred at the point where the contact force was acting.

TABLE VI FINE MESH CONVERGED VALUES

TYPES OF MESH	FINE	
VON MISES STRESS (N/m^2)	3.0001 x 10^{7}	
DIRECTIONAL DEFORMATION (TRANSVERSE) (m)	Y AXIS	Z AXIS
	8.08 x 10^{-7}	3.09 x 10^{-6}
TOTAL DEFORMATION (m)	5.7379 x 10^{-6}	

D. *Static Stress Analysis Results*

- Von-Mises Stress, Maximum Principal Stress and Shear Stress were found maximum at fixed end. i.e., at the stud holes. Minimum stress values were found at studs.
- The fixed end shows more stress because, it also shows a tendency to responds to applied boundary conditions. Since the end is fixed, the side cannot be moved so that more stress will be induced there.
- Maximum deformation was found occurring at wheel spacer body end and it is found minimum at stud holes, since it is fixed.

- The deformation was found maximum at studs because the loads are applied directly on the studs. Since studs are parts to be attached to the wheel, the operating conditions of wheel is to be provided to parts having contact with wheel.
- Since the loading conditions were provided at Y-Z axis, directional deformation was also found more at wheel spacer parts corresponding to Y-Z axis.
- Maximum Von-Mises Stress value was found to be 3.0001 x 10^7 N/m^2 and minimum value was found to be 41.651 N/m^2.
- Maximum Principal Stress obtained was 2.4347 x 10^7 N/m^2.
- Minimum Principal Stress was found to be 5.265 x 10^6 N/m^2.
- Shear Stress values observed maximum at fixed end was 1.7271 x 10^7 N/m^2 and minimum at studs was a value of 23.914 N/m^2.
- Considering deformation, maximum values were found at wheel spacer body end which were equal to 5.7379 x 10^{-6} m and minimum values were observed at fixed portion which were found to be zero.
- Transverse axis deformation was found to be 8.08 x 10^{-7} m and 3.09 x 10^{-6} m as maximum values and -8.0756 x 10^{-7} m and -5.6135 x 10^{-6} m as minimum values corresponds to Y and Z axes respectively.

The Von-Misses stress, maximum shear stress and the equivalent strain acts at the fixed end of the spacer as shown from Fig 3 to 8.

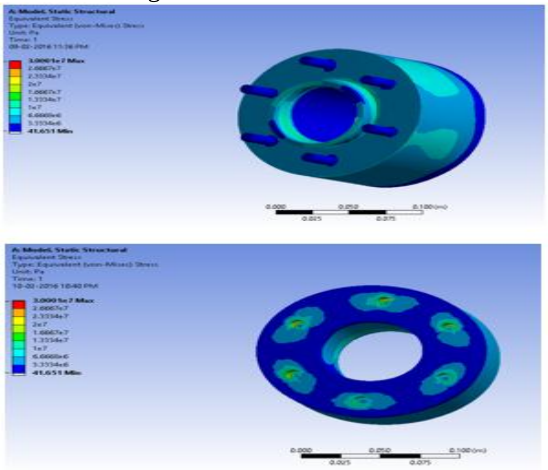

Fig 3: Von – Mises Stress

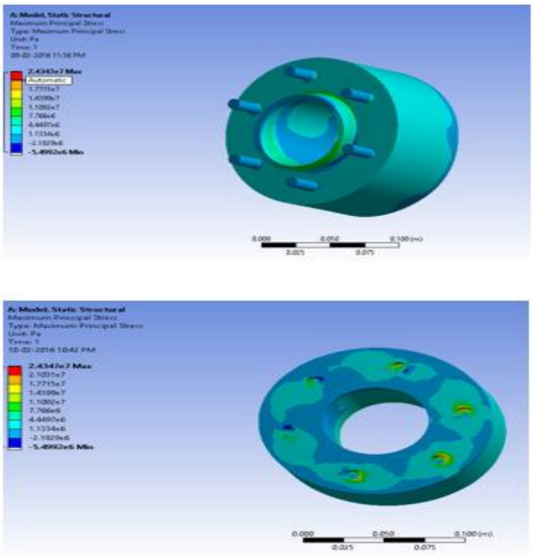

Fig 4: Maximum Principal Stress

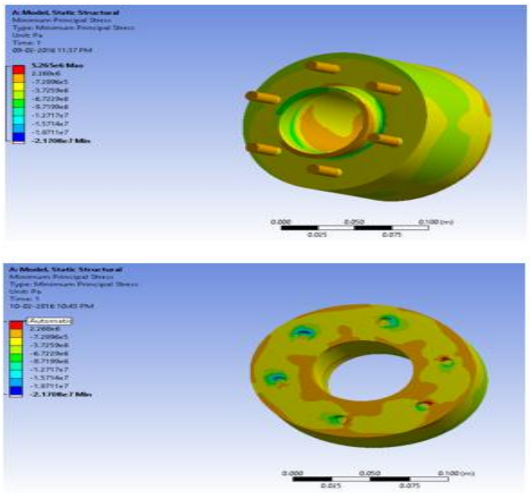

Fig 5: Minimum Principal Stress

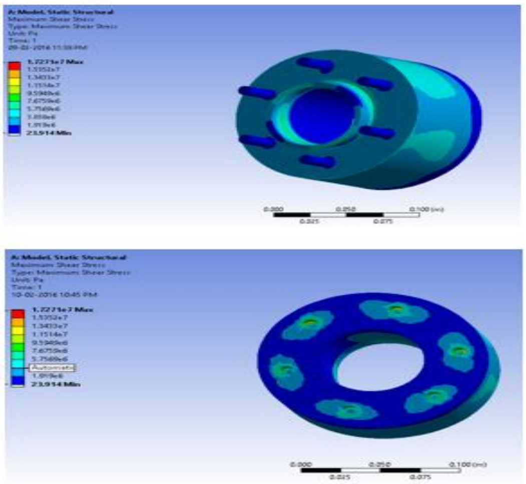

Fig 6: Maximum Shear Stress

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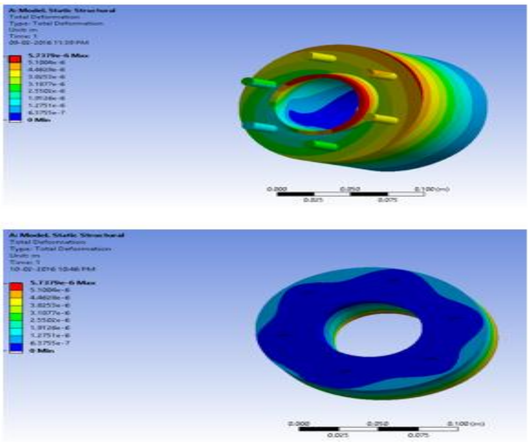

Fig 7: Total Deformation

Y AXIS Z AXIS

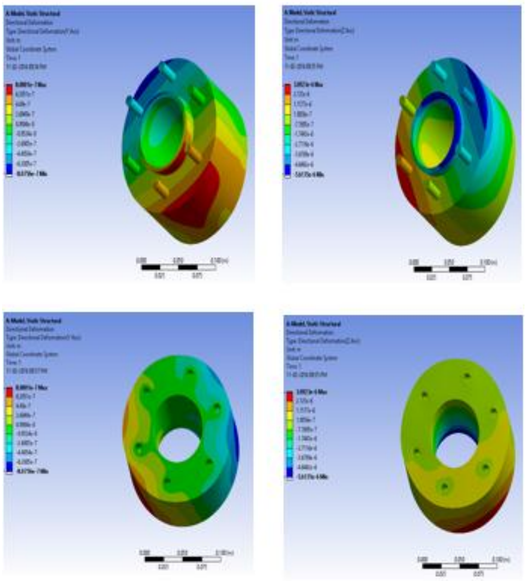

Fig 8: Directional Deformation

E. Analytical Stress Analysis Of Wheel Spacer

In-order to validate the obtained values from numerical analysis conducted using ANSYS, values are to be calculated using classical equations by analytical method. For that, the geometry has been considered as a hollow composite shaft. The spacer has been divided into two shafts and find out the maximum stress, total and directional deformations by applying super position principle. Then the numerical results has been compared and validated.

Consider the bending equation,

$$\boldsymbol{M / I = \sigma / y = E / R} \quad (1)$$

Directional deformation occurring in the wheel spacer is calculated as follows.

$$\delta_Y = \boldsymbol{ML^2 / 2EJ} \quad (2)$$

$$\delta_Z = \boldsymbol{WL^4 / 8EI + PL^3 / 3EIp} \quad (3)$$

F. Comparison Of Numerical And Analytical Stress Value

TABLE VII COMPARISON OF STATIC STRESS VALUES – BOTH NUMERICALLY AND ANALYTICALLY

PARAMETERS	ANSYS DATA		ANALYTICAL DATA	
VON MISES STRESS (N/m^2)	3.0001×10^7		3.04×10^7	
DIRECTIONAL DEFORMATION (TRANSVERSE) (m)	Y AXIS	Z AXIS	Y AXIS	Z AXIS
	8.08×10^{-7}	3.09×10^{-6}	9.53×10^{-7}	2.69×10^{-6}

The above table deals with the comparison of data obtained by numerical and analytical methods. It was found that both the set of values corresponds to Von-Mises stress and directional deformation matches.

G. Validation of Obtained Results

- The stress results obtained by numerical (by ANSYS) and analytical method almost matches.
- Similarly, the directional deformation obtained from both methods almost matches.
- Also the variation in the values were within the limit, and thus approach has been validated.

H. Findings

- Static analysis is carried out and result shows that spacer is safe under subjected operating conditions.
- Spacer has a minimum factor of safety of 8.
- Analytical results almost shows resemblance with static results.

VII. CONCLUSION

This report deals with modelling and analysis of wheel spacer with sufficient strength and stiffness. The geometrical model of the wheel spacer has been developed using SOLID EDGE ST4. Then the modelled geometry has been meshed and analysis has been performed using ANSYS WORKBENCH 15.0. Appropriate boundary conditions has been made in order to make the designed system enough strong and stiff under the operating conditions.

For the analysis purpose, modelling of a model is necessary. So, initially a model is created in SOLID EDGE ST4 according to the dimensions taken from the reference work done by Suvarna Torgal and Swati Mishra. Then the developed model is introduced to ANSYS WORKBENCH 15.0 for Static Stress analysis. The boundary conditions like load, torque and angular velocity is applied to the model. Mesh convergence study is done and fine mesh values are selected for analysis. The analysis shows that the designed system is safe under the operating conditions with a minimum safety factor of 8 for the wheel spacer.

The analytical stress analysis was done later by Euler-Bernoulli's bending equation and Coulomb's torsion equation. It was found that the values obtained almost coincides with static stress analysis values and hence validated. Then the diameter of stud was standardized and a stud diameter of 12 mm was selected. Then by considering conditions like keeping Load, Torque and Speed constant separately, the characteristic curves connecting deformation, F.O.S and stress were obtained. The graph relating load, torque, speed vs. deformation varies linearly. The F.O.S found decreasing and stress values found linear increase under these conditions. Thus the modeled geometry is sufficiently strong and stiff to operate under the prescribed operating conditions and the subsequent approximation of treating it as a hollow shaft for strength and stiffness analyses is found to be a correct and valid method.

VIII. SCOPE OF FUTURE WORK

- Optimization of the system parameters based on strength and stiffness.
- Considering different materials, stress analysis to be conducted.
- Selection of better material and its study.
- Dynamic and Fatigue analysis of wheel spacer.

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REFERENCES

[1] Sachin S Mangire, Prof. Sayed L.K, Prof. Sayyad L.B - "Static and fatigue analysis of automobile rim" International Research Journal of Engineering and Technology (IRJET) Volume: 02, Issue: 5 Aug-2015.

[2] Samuel Onoriode Igbudu, David Abimbola Fadare - "Comparison of Loading Functions in the Modelling of Automobile Aluminium Alloy Wheel under Static Radial Load", Open Journal of Applied Sciences, 2015.

[3] Turaka Venkateswara Rao, Kandula Deepthi, K.N.D. Malleswara Rao – "Design & Optimization of a Rim Using Finite Element Analysis" International Journal of Computational Engineering Research (IJCER) ISSN (e): 2250 – 3005, Vol, 04 ,Issue, 10, October – 2014.

[4] Sourav Das - "Design and weight optimization of aluminium alloy wheel" ,International Journal of Scientific and Research Publications, Volume 4, Issue 6, June 2014

[5] P. Megha Shyam, S. Girivardhan Naidu and N. Sayed Baba – "Design and Analysis of Wheel Rim using CATIA & ANSYS", IJAIEM , Volume 2, Issue 8, August 2013, ISSN 2319 - 4847

[6] Dr. Suwarna Torgal, Swati Mishra – "Stress analysis of wheel", International Journal of Mechanical Engineering and Research Volume 1 Issue 1 (Page, 34-37), ISSN: 2277-8128 (2012).

[7] N. Satyanarayana & C.H. Sambaiah - "Fatigue Analysis of Aluminum Alloy Wheel Under Radial Load", (2012)

[8] B Raghupathi, V. Srinivasa Rao, Dr. C. Udaya Kiran - "Design & Analysis of car wheel rim using FEM technique", International Journal of Computer Science information and Engg. Technologies,2012.

[9] Liangmo Wang,Yufa Chen, Chenzhi Wang, Qingzheng Wang – "Fatigue Life Analysis of Aluminum Wheels by Simulation of Rotary Fatigue Test", Journal of Mechanical Engineering 57(2011), 31-39.

[10] P.C.Lam and T.S. Srivastam – "Understanding the Influence of Pressure and Radial Load on Stress and Displacement Response of a Rotating Body: The Automobile Wheel", International Journal of Rotating Machinery Volume 2006, Article ID 60193, 1–8.