Discrete Tire Modeling for Anti-lock Braking System Simulations

Srikanth Veppathur Sivaramakrishnan

Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

> Master of Science in Mechanical Engineering

Saied Taheri, Chair Mehdi Ahmadian Robert L. West

July 01, 2013 Blacksburg, Virginia

Keywords: Tire Modeling, ABS, Rigid Ring, Enveloping Copyright 2013, Srikanth Veppathur Sivaramakrishnan

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: <u>gailmac@vt.edu</u>)

(Please ensure that Javascript is enabled on your browser before using this tool.)

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Srikanth Veppathur Sivaramakrishnan

Description of item under review for fair use: Figure 2.1: Detailed view of a pneumatic tire. Adapted from Zegelaar, P. (1998). The dynamic response of tyres to brake torque variations and road unevennesses. Delft University of Technology. Used under fair use, 2013.

Report generated on: 08-18-2013 at : 22:40:06

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: <u>gailmac@vt.edu</u>)

(Please ensure that Javascript is enabled on your browser before using this tool.)

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Srikanth Veppathur Sivaramakrishnan

Description of item under review for fair use: Figure 2.2: Classication of tire models. Adapted from Pacejka, H. B. (2012). Tire and Vehicle Dynamics (3rd ed.). Butterworth-Heinemann. Used under fair use, 2013.

Report generated on: 08-18-2013 at : 22:41:12

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: <u>gailmac@vt.edu</u>)

(Please ensure that Javascript is enabled on your browser before using this tool.)

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Srikanth Veppathur Sivaramakrishnan

Description of item under review for fair use: Figure 2.3: Tire enveloping property. Adapted from Zegelaar, P. (1998). The dynamic response of tyres to brake torque variations and road unevennesses. TU Delft. Used under fair use, 2013.

Report generated on: 08-18-2013 at : 22:41:43

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: gailmac@vt.edu)

(Please ensure that Javascript is enabled on your browser before using this tool.)

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Srikanth Veppathur Sivaramakrishnan

Description of item under review for fair use: Figure 2.4: Tire enveloping models. Adapted from Schmeitz, A. J. C. (2004). A Semi-Empirical Three-Dimensional Model of the Pneumatic Tyre Rolling over Arbitrarily Uneven Road Surfaces. Delft University of Technology. Used under fair use, 2013.

Report generated on: 08-18-2013 at : 22:42:09

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: gailmac@vt.edu)

(Please ensure that Javascript is enabled on your browser before using this tool.)

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Srikanth Veppathur Sivaramakrishnan

Description of item under review for fair use: Figure 2.5: General classication of dynamic tire models. Adapted from Schmeitz, A. J. C. (2004). A Semi-Empirical Three-Dimensional Model of the Pneumatic Tyre Rolling over Arbitrarily Uneven Road Surfaces. Delft University of Technology. Used under fair use, 2013.

Report generated on: 08-18-2013 at : 22:42:44

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: gailmac@vt.edu)

(Please ensure that Javascript is enabled on your browser before using this tool.)

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Srikanth Veppathur Sivaramakrishnan

Description of item under review for fair use: Figure 3.1: Global coordinate system. Adapted from Zegelaar, P. (1998). The dynamic response of tyres to brake torque variations and road unevennesses. Delft University of Technology. Used under fair use, 2013.

Report generated on: 08-18-2013 at : 22:43:12

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: gailmac@vt.edu)

(Please ensure that Javascript is enabled on your browser before using this tool.)

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Srikanth Veppathur Sivaramakrishnan

Description of item under review for fair use: Figure 3.2: Tandem elliptical cam model. Adapted from Schmeitz, A. J. C. (2004). A SemiEmpirical Three-Dimensional Model of the Pneumatic Tyre Rolling over Arbitrarily Uneven Road Surfaces. Delft University of Technology. Used under fair use, 2013.

Report generated on: 08-18-2013 at : 22:45:17

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: <u>gailmac@vt.edu</u>)

(Please ensure that Javascript is enabled on your browser before using this tool.)

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Srikanth Veppathur Sivaramakrishnan

Description of item under review for fair use: Figure 3.3: Rigid ring tire model. Adapted from Zegelaar, P. (1998). The dynamic response of tyres to brake torque variations and road unevennesses. Delft University of Technology. Used under fair use, 2013.

Report generated on: 08-18-2013 at : 22:44:22

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: <u>gailmac@vt.edu</u>)

(Please ensure that Javascript is enabled on your browser before using this tool.)

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Srikanth Veppathur Sivaramakrishnan

Description of item under review for fair use: Figure 3.4: Deformations in the tire. Adapted from Zegelaar, P. (1998). The dynamic response of tyres to brake torque variations and road unevennesses. Delft University of Technology. Used under fair use, 2013.

Report generated on: 08-18-2013 at : 22:45:43

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: <u>gailmac@vt.edu</u>)

(Please ensure that Javascript is enabled on your browser before using this tool.)

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Srikanth Veppathur Sivaramakrishnan

Description of item under review for fair use: Figure 3.5: Tire-road contact model. Adapted from Zegelaar, P. (1998). The dynamic response of tyres to brake torque variations and road unevennesses. Delft University of Technology. Used under fair use, 2013.

Report generated on: 08-18-2013 at : 22:46:09

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: gailmac@vt.edu)

(Please ensure that Javascript is enabled on your browser before using this tool.)

Virginia Tech ETD Fair Use Analysis Results

This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.

Name: Srikanth Veppathur Sivaramakrishnan

Description of item under review for fair use: Figure 5.1: Tire dimensions. Adapted from Zegelaar, P. (1998). The dynamic response of tyres to brake torque variations and road unevennesses. Delft University of Technology. Used under fair use, 2013.

Report generated on: 08-18-2013 at : 22:46:38

Based on the information you provided:

Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*