Design strategy for concept design of hybrid bio-composite automotive anti-roll bar using TRIZ

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ABSTRACT – In this study, development of concept design of hybrid bio-composite automotive anti-roll bar (ARB) has been performed using TRIZ as its design strategy. Using Contradiction Matrix and 40 Inventive Principles, TRIZ suggested the concept design of the automotive ARB could consist of ribs for the reinforcement and multi diameter of ARB's arms in order to reduce weight. The new design improved the stiffness by reduces the maximum displacement by 22.5%. Thus, TRIZ has suggested a new concept design that could satisfy the properties of the materials without affecting its functions and performance.

1. INTRODUCTION

Function of automotive anti-roll bar (ARB) is to generate reactive force by compressing the suspension on the adjacent side of the vehicle when suspension on the other side is compressed. ARBs that made from steel are considered heavy and when they are configured in tubular shape, they are susceptible to breakage [1]. With recent awareness on environment-friendly products and sustainability, it shows that hybrid bio-composites could be one of the substitute materials of steel and could be used in many applications in automotive industry especially ARB [2]. A suitable design of ARB is needed due to the critical size and shape of ARB regarding on its functions and operation that linked to suspension in vehicle [3]. Hence, a suitable concept design including determination of geometry of lightweight ARB is the focus area in this study. Moreover, there is a study by Doody [4] that found hybrid carbon fiber could be used as a substitute material for lightweight ARB. However, the shape and size of ARB should be different from steel-based ARB. Therefore, conflict between the features of ARB and properties of hybrid bio-composite material that applied in the ARB is going to be solved by tools in TRIZ in order to generate an inventive solution for the improvement of the hybrid bio-composite automotive ARB.

2. METHODOLOGY

TRIZ was developed by Atlshuller to solve inventive problems using scientific approach from patents data analysis by identifying innovative solution [5]. TRIZ tools that are commonly practiced in product design and development are Contradiction Matrix and 40 Inventive Principles because of simplicity and direct approach in problem solving. Thus, in this study, application of both tools are selected for design development of hybrid bio-composite ARB.

Based on the operation and principle of ARB, the stiffness of the ARB is defined by the geometry and material properties and strongly depends on the diameter of the ARB as shown in the equation below:

$$c = \frac{G\pi d^4}{32a^2b} \quad (1)$$

where G is modulus of shear, a and b are defined as length for arm and centre respectively as in Figure 1 and d is diameter of the ARB.

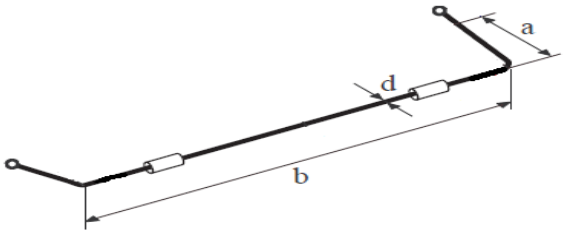

Figure 1 Anti-roll bar

From equation (1), the Engineering Contradiction in the form of improving parameter and worsening parameter is defined. In this case, Engineering Contradiction is *"If the diameter of the bar is increase, the stiffness of the bar is improved but it is ultimately gaining more weight"*. This means that in order to improve the stiffness of the bar, the diameter of the bar should be increased; however it would require more weight added on the bar. Thus, the improving parameter are volume of moving object (#7), strength (#14) and reliability (#27). The worsening parameter in this case is weight of moving object (#1).

3. RESULTS AND DISCUSSION

As mentioned in previous section, TRIZ has suggested a few possible general solutions to solve the contradiction. The selected Inventive Principles that are considered as the most appropriate solutions are #2

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taking out, #3 local quality and #40 composite materials. In Table 1, specific solution strategies are developed in order to adopt in the problem of design ARB.

Table 1 Specific solution strategy based on the TRIZ general solution principles,

TRIZ general solution principles	**Solution descriptions**	**Specific solution strategy**
#2 Taking out	Separate an interfering part or property from an object, or single out the only necessary part (or property) of an object	Cross-sectional of the ARB could be in a hollow shape by taking out unnecessary part while maintaining the performance of the component [6].
#3 Local quality	(a) Change an object's structure from uniform to non-uniform, change an external environment (or external influence from uniform to non-uniform. (b) Make each part of an object function in conditions most suitable for its operation and fulfil a different and useful function	(a) Vary diameter of the component in order to handle the high stress at critical point along the bar. The value depends on the value of stress concentration and safety factor [7]. (b) Outer part of the solid bar or inner part of hollow bar could be designed with ribs to reinforce and strengthened the structure [8].
#40 Composite materials	Change from uniform to composite (multiple) materials	Use hybrid composition where natural fiber is combined with high strength synthetic fiber like glass to increase the strength.

Based on the analysis of Inventive Principles suggested previously, the reinforcement of ribs may improve the ARB stiffness [9]. The reinforcement of ribs with multi diameter of ARB's arms in new design reduces the maximum displacement by 22.5% and improved the stiffness. The new concept design of the ARB is shown in Figure 2.

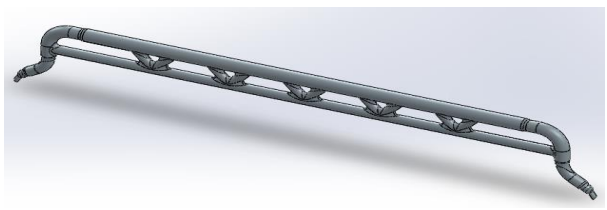

Figure 2 Concept design of hybrid bio-composite ARB.

4. CONCLUSION

In conclusion, to incorporate hybrid natural fiber composite material with design of automotive component, design strategy like in TRIZ could be used in order to develop suitable design for the automotive components without affecting their function and performance. In this case, concept design of hybrid bio-composite automotive ARB had been developed through methods that suggested in TRIZ. The new concept design has been reinforced and strengthened with ribs at bend areas of ARB. In addition, future works will be conducted to evaluate the properties and manufacturability of hybrid bio-composite automotive ARB for comparison with current design of ARB.

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REFERENCES

[1] O. Renner, M. Krahl, M. Lepper, and W. Hufenbach, "Stabilizer Bar of Fiber Reinforced Plastic Composite and Method for Its Manufacture," US 8,668,212 B2, 2014.

[2] O. Faruk, A. K. Bledzki, H.-P. Fink, and M. Sain, "Progress Report on Natural Fiber Reinforced Composites," *Macromol. Mater. Eng.*, vol. 299, no. 1, pp. 9–26, 2014.

[3] H. Bayrakceken, S. Tasgetiren, and K. Aslantas, "Fracture of an automobile anti-roll bar," *Eng. Fail. Anal.*, vol. 13, no. 5, pp. 732–738, 2006.

[4] M. Doody, "Design and Development of A Composite Automotive Anti-Roll Bar," 2013.

[5] T.-S. Li and H.-H. Huang, "Applying TRIZ and Fuzzy AHP to develop innovative design for automated manufacturing systems," *Expert Syst. Appl.*, vol. 36, no. 4, pp. 8302–8312, May 2009.

[6] K. Sharma, P. M. Bora, and P. K. Sharma, "Hollow Cross-Section vs . Solid Cross-Section & Increasing the Diameter of Solid Cross-Section by using finite element Analysis of Anti-Roll Bar," *Int. J. Adv. Res. Sci. Eng.*, vol. 1, no. 1, pp. 1–11, 2012.

[7] P. M. Bora, "Vehicle Anti-Roll Bar Analyzed Using FEA Tool ANSYS," *Int. J. Adv. Technol. Eng. Sci.*, vol. 2, no. 7, pp. 130–136, 2014.

[8] M. R. Mansor, S. M. Sapuan, E. S. Zainudin, A. A. Nuraini, and A. Hambali, "Conceptual design of kenaf fiber polymer composite automotive parking brake lever using integrated TRIZ–Morphological Chart–Analytic Hierarchy Process method," *Mater. Des.*, vol. 54, no. 0, pp. 473–482, Feb. 2014.

[9] A. Kobayashi, "Torsion Beam Type Rear Wheel Suspension System," US 7,946,600 B2, 2011.