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Aerodynamic Simulation of Car Bumper Products Made of Rattan Fiber Composite Material

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Abstract. The development of composite materials by utilizing environmentally friendly natural fibers aims to become an alternative material to replace conventional materials. Natural fiber composite materials are continuously being developed to make automotive components. This study aims to develop a car bumper made of rattan fiber composite material combined with fiberglass. The research is focused on simulating the aerodynamics of the designed bumper. The simulation uses Computational Fluid Dynamics (CFD) software, with an assumed maximum speed of 120 km/h. Based on the simulation results, it is found that the maximum pressure that occurs on the surface of the bumper is 8,421e+02 Pa, where this pressure is almost evenly distributed on the frontal surface of the front bumper. Surface pressure due to air flow when the vehicle is running at high speed certainly has an influence on the strength and rigidity of the structure of the bumper. Therefore, this study will continue with a structural strength analysis. The results of this study will be a reference for further research.
Keywords: Simulation, CFD, aerodynamics, bumper, rattan composite material.

INTRODUCTION

The use of rattan fiber as a composite material in the automotive sector is very open. On the other hand, Indonesia has an enormous potential in producing rattan fiber. Rattan fiber has numerous beneficial characteristics such as recyclable, renewable, environmentally friendly, and having a good strength [1], [2].

In this study, a car bumper product was developed using epoxy rattan fiber composite material. Bumper products serve to protect the car from collisions, provide an aerodynamic effect on the car, and give an impression on the car's aesthetics. The higher the speed of the car, it requires good and precise aerodynamic support. The aerodynamic component at the front of the car is very important because it splits the wind first when the car is moving at high speed. Therefore, to create balance at the front, the designers were very concerned about the bumper. At the same time, cars also use air as a cooling aid. A good bumper design will increase the aerodynamic effect and at the same time help cool the radiator and intercooler. A good bumper design can also help bypass the wind that passes through the engine bay. Air volume and air velocity entering from the front can function to cool the intercooler [3-10].

The focus of the research is to analyze the aerodynamics of the car bumper product design which was developed using rattan fiber composite material. Aerodynamic analysis is very important because a good bumper product provides good aerodynamic effects, making the car safer and more comfortable when used, especially at high speeds. [5], [6], [11-15.] The results of the aerodynamic simulation are the basis for the further development of car bumpers, especially in terms of safety.

METHOD

Aerodynamic analysis is done by conducting simulations using Computational Fluid Dynamics (CFD) software. The software used is Siemens Simcenter Star CCM+ version 2021.1.1. In this study, the front bumper of the car was developed. The rattan fiber composite material has the following characteristics:

TABLE 1. Properties of rattan fiber reinforced composite material

Density	4.7E-2 kg/m^3
Young’s modulus	6280 MPa
Poisson’s ratio	0.27
Yield strength	22.1MPa
Ultimate tensile strength	32.65MPa

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In CFD analysis, the number and type of mesh cells are important factors for the success of the simulation iteration process in order to achieve a convergent value with high accuracy, along with data on the type of mesh and the number of cells built from the meshing process [3], [6], [7], [9], [11].

TABLE 2. Meshing Process

Name	Feature of mesh	Parameter of mesh
Mesh of totally domain	Automatic meshing Tetrahedral mesh Prism Layer Volume mesh refinement Surface remaster	Number of Cells: 10,277,402 Number of Faces: 20,343,978 Number of Vertex: 1,996,125
Mesh of solid domain	Tetrahedral mesh Volume of mesh refinement	Number of Cells: 257,812 Number of Faces: 431.098 Number of Vertex: 85.143
Mesh of fluid domain	Tetrahedral mesh Prism Layer Volume of mesh refinement	Number of Cells: 10,019,590 Number of Faces: 19,912,880 Number of Vertex: 1,910,982

Boundary Conditions in the aerodynamic simulation process as shown in Figure 1.

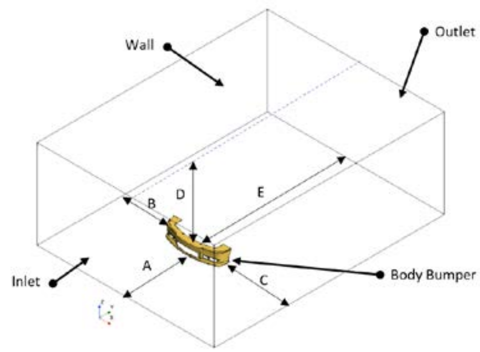

FIGURE 1. Isometric Boundary Conditions

TABLE 3. Data of Simulation

Parameters	Condition	Parameters
Fluid	Air Temperature: 30°C Dimension: A, B, C & D = 1x length total of bumper E= 2x length total of bumper	ρ: 1.164 kg/m^3 μ: 1.872e-5 kg/m·s v: 1.608e-5 m^2/s Dimension of Domain Fluid: P: 6,500mm L: 5,000mm T: 2,500mm
Inlet	Velocity inlet:	U: 120 km/h (orientation: Y+)
Outlet	Pressure Outlet	P: 0 Pa (Gauge Pressure)
Wall	Non-Slip Wall Conditions	Symmetry wall is applied to the left, right, and top wall surfaces. Wall condition is applied to the lower wall surface
Body Bumper	Non-Slip Wall Condition Smooth surface	P: 1620.56mm L: 472mm T: 313.27mm Frontal surface area A: 3.562856e-01m^2
Gravity	Orientation: -Z	g: 9.81m/s^2
Computations	-Reynolds-Average Navier- Stokes (RANS)	-Realizable k-$\mathcal{E}$ two layer -Standard k-$\mathcal{E}$
Simulation solver	Implicit unsteady, Constant density Fluid, Segregate flow, two-layer Y+ wall treatment. Solid mechanics stress with Fluid to Structure Interactions, Rayleigh damping for stability	Material properties: Rattan fiber reinforced composite material Density: 4.7E-2 kg/m^3 Young's modulus: 6280 MPa Poisson's ratio: 0.27 Yield strength: 22.1MPa Ultimate tensile strength: 32.65MPa

The type of mesh used is a tetrahedral mesh type because it has a relatively optimal level of accuracy for computational effort and is suitable for reliable external flow simulations. The application of surface remesher is carried out so that the interface between the mesh surfaces of the fluid domain and solid domain can have a high level of interfacial conformity.

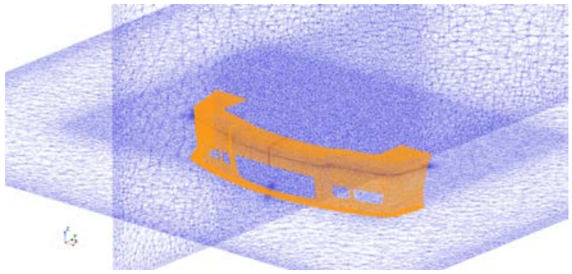

FIGURE 1. Isometric of Mesh

RESULT AND DISCUSSION

As shown in Figure 4, the residual value in the iteration decreases with the increase in the number of iterations. At the 300th iteration and above, the residual value in the continuity parameter is close to constant, namely 5e-6. It can be concluded that the results of this simulation have reached a converged condition.

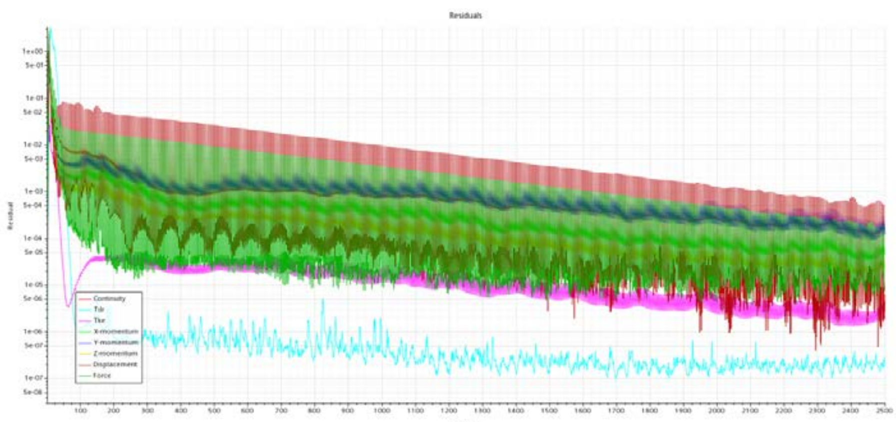

FIGURE 4. Iteration graph against residuals in bumper simulation

In addition, the convergence level is also indicated by monitoring the drag force results from the bumper as shown in Figure 5. The drag force values appear to be close to stable.

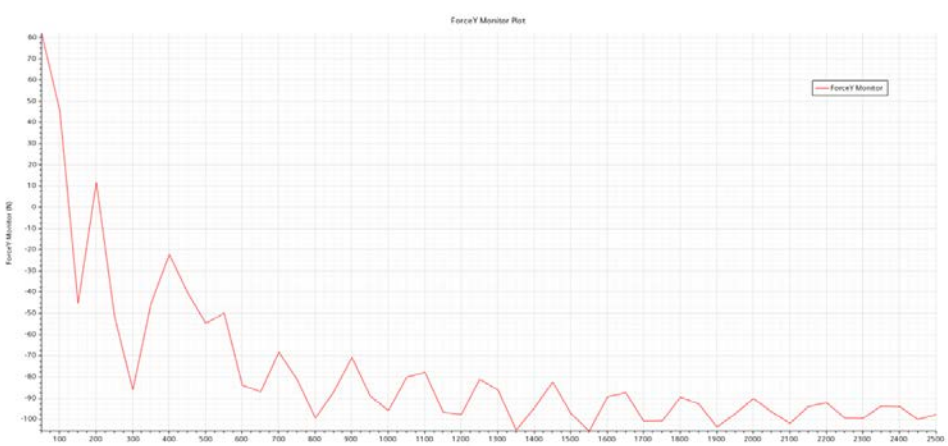

FIGURE 2. Iteration graph of the drag in the direction of Y axis

This study aims to determine the effect of air pressure on the vehicle bumper when the vehicle is moving at a speed of 120 km/h. The air flow that hits the surface of the bumper will cause surface pressure, measured by pressure per unit area. The pressure data is then integrated to get the drag force value. Then, the drag force in the frontal direction of the vehicle can be known. Figure 5 shows that the total value of the frontal force in the Y-axis direction is 97.774 N.

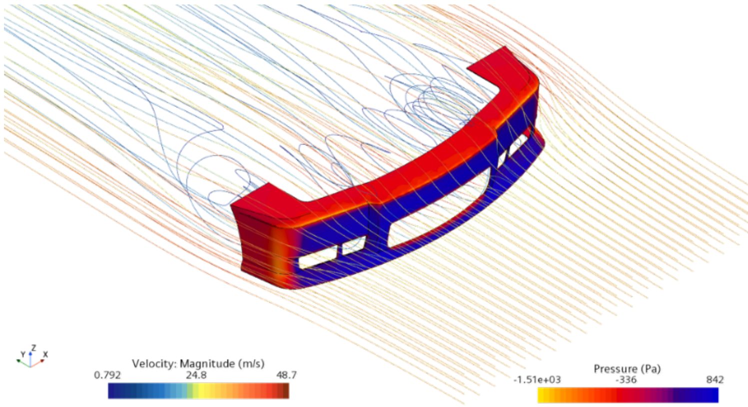

FIGURE 3. Streamline simulation results and pressure distribution on the bumper surface

The maximum pressure that occurs on the surface of the bumper is 8.421e+02 Pa, where this pressure is almost evenly distributed on the frontal surface of the front bumper. Surface pressure due to air flow when the vehicle is running at high speed certainly has an influence on the strength and stiffness of the bumper structure, so this research will continue with structural strength analysis. Figure 6 shows the results of the simulation of the pressure distribution on the surface of the bumper with the CFD process. In the middle area, there is a relatively uniform and high pressure, where the maximum surface pressure due to air velocity is 842 Pa. This is because stagnation pressure occurs in the middle of the bumper area where the surface of the bumper is in the form of an arch with a large enough curvature value, so that the air flow hits the surface near the perpendicular so that the normal force tends to be higher than the shear force. This stagnation pressure is also very clearly seen in Figure 8 where the greatest pressure occurs in that area. On the front surface of the left and right sides of the bumper, the air pressure is relatively lower due to the smaller curvature value of the curved surface of the bumper in this area. In this part of the bumper, the air is relatively easily deflected towards the side of the bumper so that the shear force is higher than the normal force [12-18].

Figure 9 shows the distribution of air pressure in the XY plane, the left and right-side surfaces and the upper surface have relatively low pressure. Airflow paths can also easily enter the middle and bottom airflow holes on the left and right of the bumper. However, backflow phenomenon occurs as shown in Figure 7 because the model used in CFD analysis does not include the car as a whole. Therefore, the area behind the bumper becomes empty and backflow occurs. However, because the focus of this study is to obtain the distribution of air pressure on the surface of the bumper, this backflow phenomenon can be ignored [12-18].

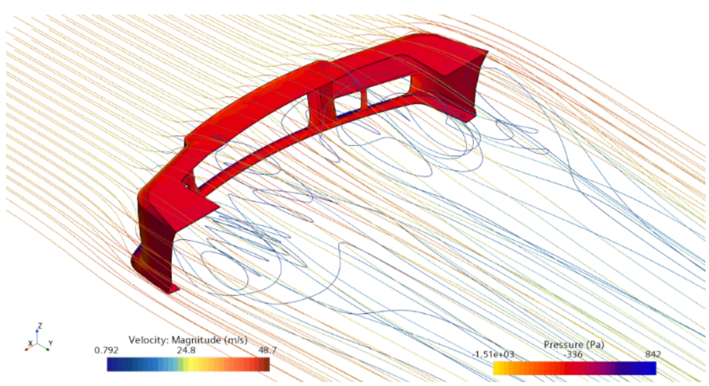

FIGURE 4. Backflow phenomenon on the rear bumper

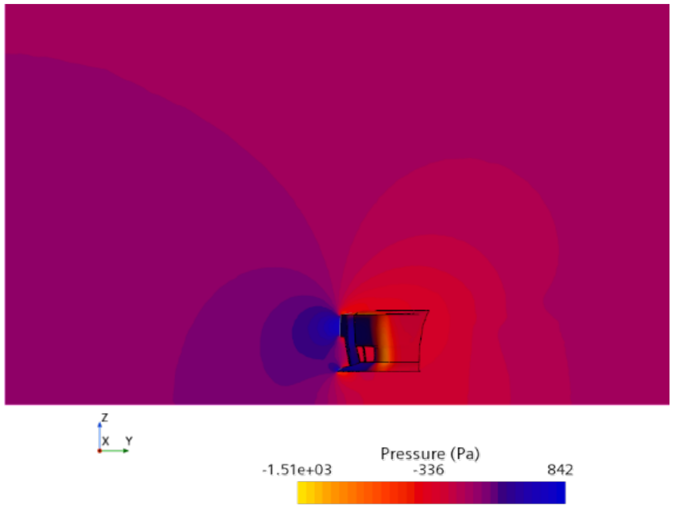

FIGURE 5. YZ plane of air pressure distribution around the bumper surface

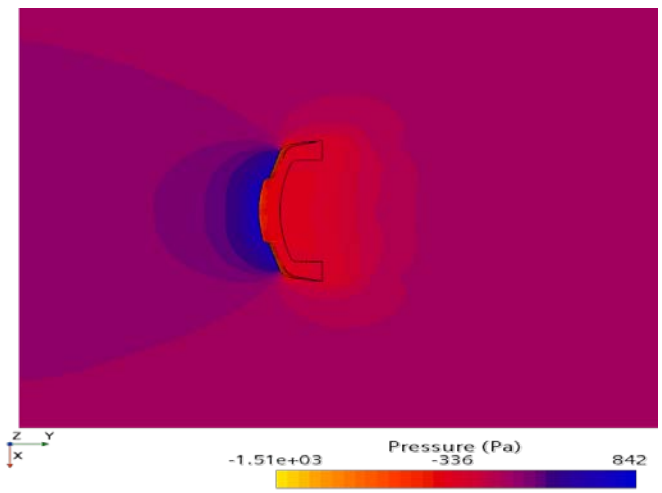

FIGURE 6. Distribution of air pressure in the XY plane

The maximum pressure that occurs on the surface of the bumper is 8.421e+02 Pa, where this pressure is almost evenly distributed on the frontal surface of the front bumper. Surface pressure due to air flow when the vehicle is running at high speed certainly has an influence on the strength and stiffness of the structure of the bumper, therefore this study will continue with a structural strength analysis.

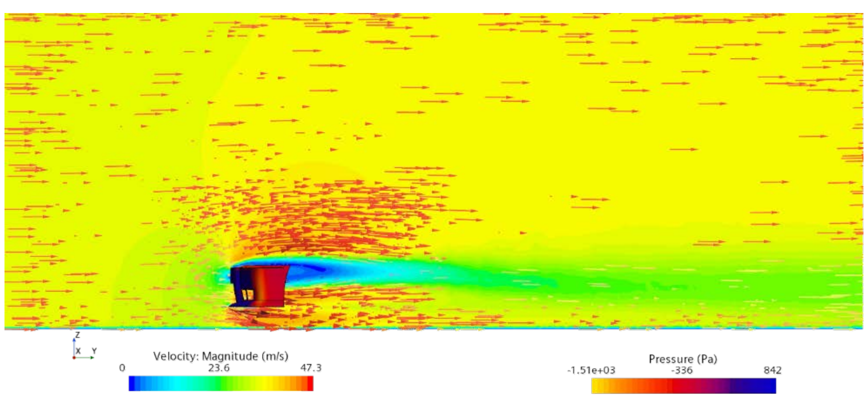

FIGURE 7. Distribution and velocity vector on the YZ plane

As seen in the distribution of velocity and velocity vector in the YZ plane in Figure 10 and 11, the air flow can be easily deflected to the top and bottom of the vehicle.

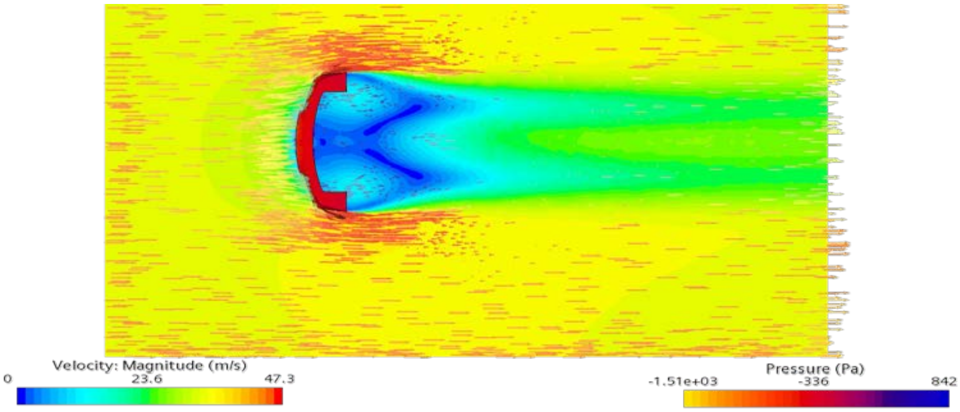

FIGURE 8. Airflow distribution and air velocity vector in the XY plane above view

In the simulation applying the Fluid Structure Interaction (FSI) method, the compressive force that occurs due to the air flow rate hitting the entire surface of the bumper is transferred through the automatic mesh cell mapping method. The accuracy level of this method is relatively higher than the manual mapping method. However, to achieve a high level of accuracy, the interface of each mesh cell must have a high suitability value.

CONCLUSION

Simulations have been carried out to analyze the aerodynamic phenomena that occur in car bumper products made of rattan fiber composite material with a maximum speed of 120 km/h. The maximum pressure that occurs on the surface of the bumper is 8.421e+02 Pa, which is evenly distributed on the frontal surface of the front bumper. Surface pressure due to air flow when the vehicle is running at high speed certainly has an influence on the strength and stiffness of the structure of the bumper. Therefore, this study will continue with a structural strength analysis. The results of this study become a reference for further development.

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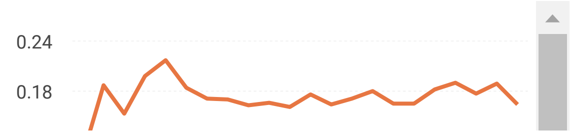

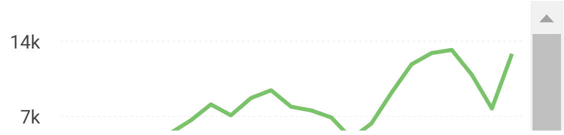

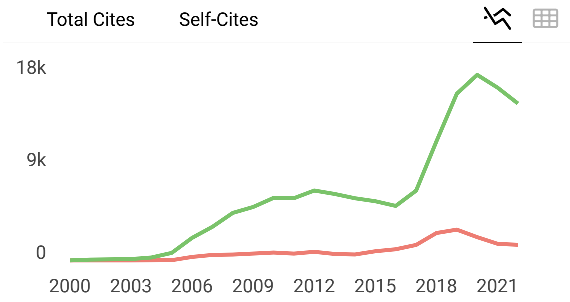

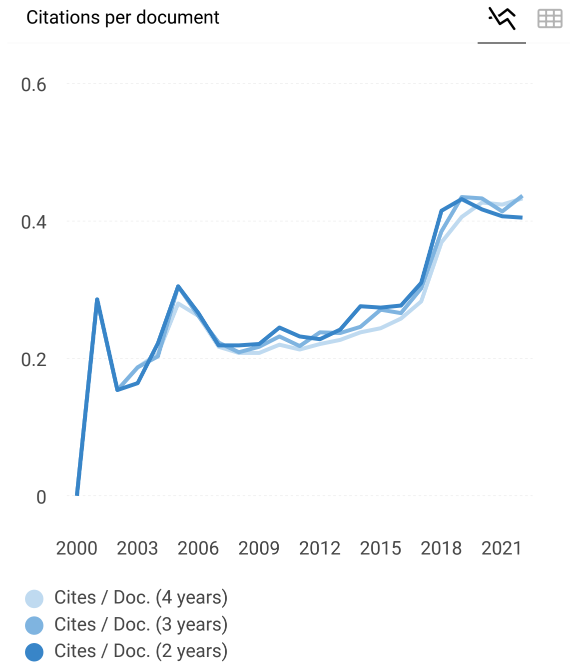

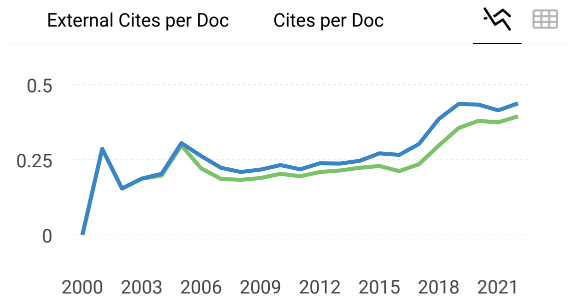

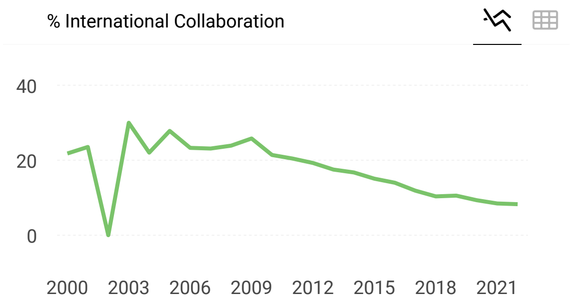

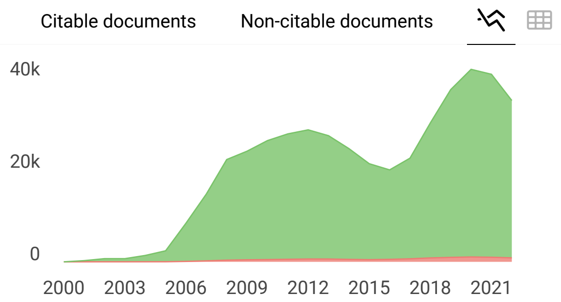

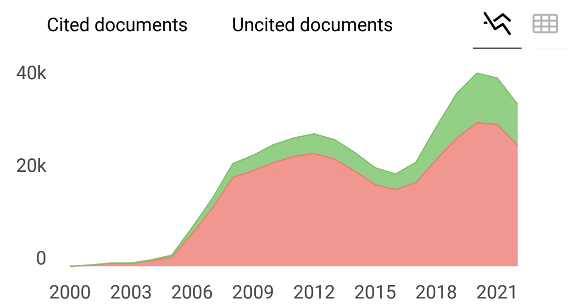

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