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Simulation on the influence of the shape of the carabiner as a hanging accessory on stress distribution using Autodesk Fusion 360

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Abstract: Engineering and innovation in the manufacturing process will continue to be carried out. This aims to ensure that there are always improvements in every product made, both in terms of design, materials used, and how the production process is carried out. Product design innovation is often also aimed at efficiency and reducing product production costs. Innovation in a product must be to improve, not reduce the value and usefulness of the product being made. The aim of this research is to determine the distribution of stress and strain as well as the safety factor of carabiners as hanging accessories using polypropylene polymer material. The research uses experimental methods, namely observing the simulation results that occur in the form of stress, strain and safety factors, as well as knowing the cause and effect phenomena that occur in the design of a carabiner for an accessory. By changing the shape of each design to the upper end of the frame in the direction of the carabiner gate, R15, R30 and R45. As well as varying the load given by 10 N to 100 N, with an increase in force of 10 N in each simulation carried out, with axial and vertical loading directions. By ignoring the type of gate and the shape of the connection on the carabiner gate. The different shapes in each carabiner design cause differences in the tension distribution that occurs. The R15 design has a maximum stress value at a load of 100 N, namely 25.03 MPa, the R30 design is 33.78 MPa, and the R45 design is 63.61 MPa. The vertical loading direction achieves a good safety level of 4.0 at a load of 20 N in the R15 and R30 designs. Meanwhile, axial loading does not achieve product safety targets. The difference in calculating the factor of safety is 4.0 between the results of computer computing and the results of analytical calculations using a formula, namely 1% of the maximum limit of 5%.

Keywords: Polymer injection molding; variations in carabiner design; strain; voltage; safety factor

1. INTRODUCTION

Polymer injection molding is a process where thermoplastic materials melt under the influence of heating, and rub against each other in a hollow tube, then are injected into a mold, then cooled with water or oil so that the product hardens [1,2]. A polymer is a material in the form of a long, repeating molecular chain of atoms, which is composed of millions of monomers linked by a covalent bond through the polymerization process [1]. In determining the formation of products using polymer materials using the plastic injection process, one must pay attention to the properties of the polymer against changes in temperature or based on its heat resistance, namely thermoset polymers and thermoplastic polymers, this type of polymer will melt at a certain temperature and if processed at the appropriate temperature it can be formed as follows. mold and the resulting temperature changes, however, the advantage of this polymer is that it has reversible properties or is returned to its initial form by a certain process [1,2]. *A carabiner is a hook tool in the form of a metal loop that is used to attach one point of an object to another part of the object so that it can be connected quickly, passing through the gate (door) or hook* [3-5]. Because of the many functionalities of this tool, it is even used as a hanging accessory product that will accept a maximum load of 1.5 kg. It will be ineffective if the carabiner is made using metal material which requires more resources to be spent [6-8]. This research aims to provide alternative designs for a product to make it more effective, but not reduce the safety factor of the product being made [9]. This research was carried out with the aim of knowing the stress distribution that occurs in each design made through a static stress analysis simulation using the finite element method, to be able to know the stress, strain and factor of safety values of the design made

[10-13]. The design tested is the upper end of the frame of the carabiner in the same direction as the nose and gate of the carabiner with design variations of R15, R30 and R45, which will then be carried out in two loading directions, namely in the vertical direction and in the horizontal direction with load variations of 10 each. N to 100 N.

The different shapes in each carabiner design cause differences in the tension distribution that occurs. The R15 design has a maximum stress value at a load of 100 N, namely 25.03 MPa, then the R30 design is 33.78 MPa, and the R45 design is 63.61 MPa [11,12]. The R30 design has an advantage in the gate opening range of 26.07 mm, a difference of 6.56 mm compared to the R15 design. The vertical loading direction has a product safety level of 4.0 achieved at a load of 20 N for the R15 and R30 designs. Meanwhile, the axial load is only able to withstand 5 N to reach the target of 4.0. The difference in the factor of safety calculation of 4.0 between the results of computer computing and the results of analytical calculations using a formula is 1%, this value is still reasonable because it is still below the maximum tolerance value of 5% [14-16].

2. METHOD

The research flow can be seen in Figure 1. The research uses an experimental method using the finite element method with static stress simulation, to determine the cause and effect phenomena that occur in the design. With data design methods using quantitative methods. The research used polypropylene polymer material with the carabiner design profile sizes as follows: product diameter 5 mm and total product length 63.5 mm, with a top spine frame radius of 14.5 and a bottom end frame radius of 14 mm, for further clarity on the design of each Each carabiner can be seen in Figure 2. Table 1 shows the material properties used in the research.

Table 1. Material properties of polypropylene polymer.

Name	Material Properties	Value	Units
Basic Thermal	Thermal Conductivity	1,980e-01	Kg/mm^3
	Specific Heat	2,731	J/(g·°C)
	Thermal Expansion Coefficient	90,500	µm/(m·°C)
Mechanical	Young's Modulus	1,340	GPa
	Poisson's Ratio	0,39	
	Shear Modulus	757,000	MPa
	Density	0,899	g/cm^3
Strength	Yield Strength	30,400	MPa
	Ultimate Tensile Strength	36,500	MPa

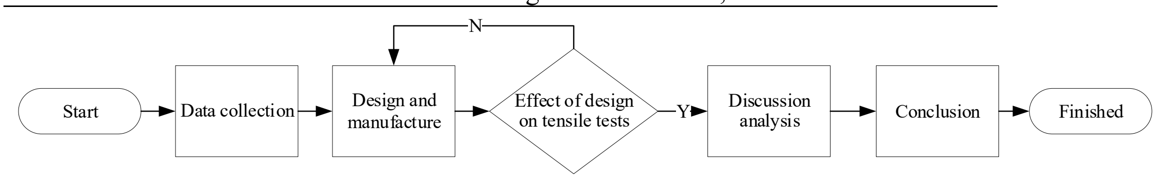
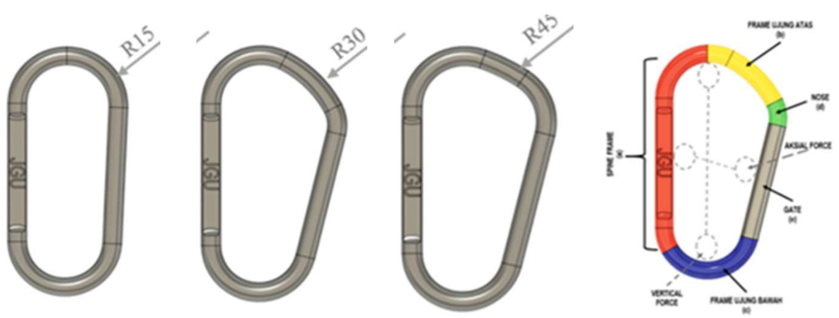


Figure 1. Research flow diagram

The three carabiner designs made have different sizes at the top end frame of the carabiner, namely R15, R30 and R45, to see more clearly in Figure 2.



(A) (B) (C) *Master Carabiner*

Figure 2. Research variables with variation values (A) R15, (B) R30, and (C) R45.

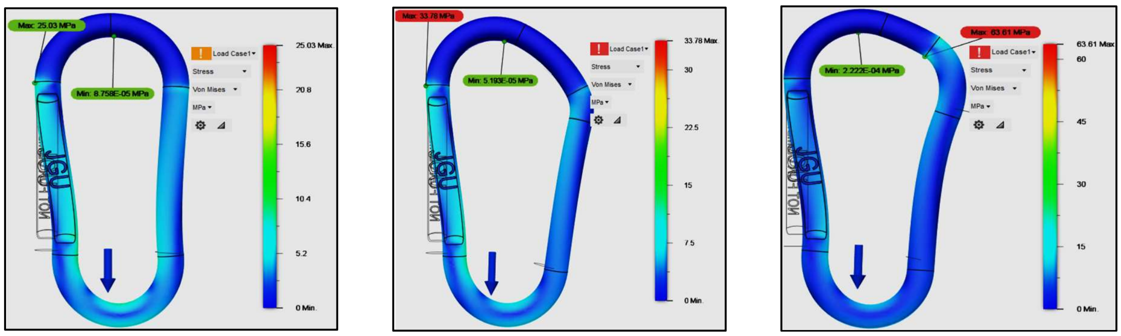
Furthermore, to find out the validation of the safety factor of the carabiner design being made, it can be calculated by dividing the yield strength value of the material divided by the stress value that occurs in the simulation. For more details, you can use the following equation:

$$sf = \frac{Yield\ Stress}{Calculated\ Stress} \tag{1}$$

3. RESULTS AND DISCUSSION

3.1 Von mises stress analysis

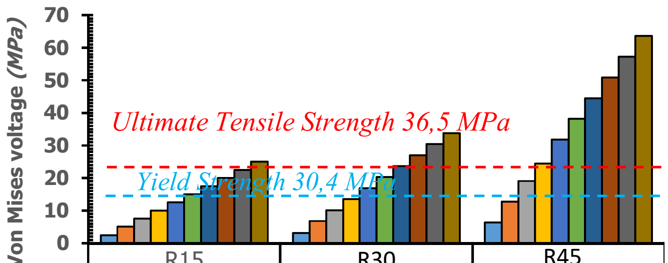
Figure 3 (A), (B), and (C) show the static stress simulation results of the carabiner design with a load of 100 N each. The R15 von Mises stress is 25.03 MPa, the R30 design is 33.78 MPa, the R45 design amounting to 63.61 MPa. The von Mises stress of R15 is still below the yield strength value of the material used, namely 30.4 MPa. There is a change in the position of the von Mises stress in the R45 design to be located on the inside of the top end of the frame. The results of the stress analysis (Von Mises) must be below the yield strength value [14,16].



(A) (B) (C)

Figure 3. Von mises stress for designs (A) R15, (B) R30, and (C) R45.

The static stress simulation results for each design can be seen in Figure 4. From the simulation results in Figure 3, it can be seen that the stress value that occurs will always be directly proportional to the applied loading value. However, on the contrary, the product safety value is actually inversely proportional, that is, the greater the stress, strain and load applied, the more the level of product safety will be reduced.

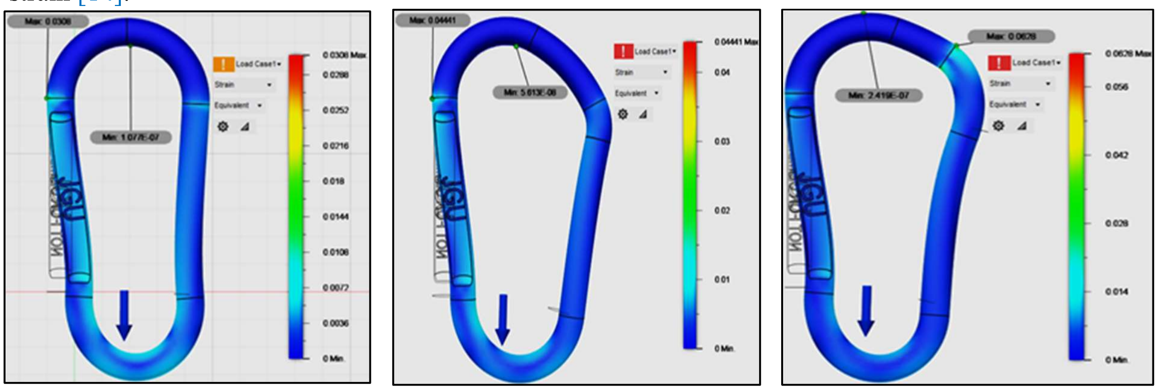


	R15	R30	R45
10N	2.501	3.08	6.324
20N	5.004	6.763	12.7
30N	7.507	10.14	19.07
40N	10.01	13.52	24.43
50N	12.51	16.89	31.79
60N	15.02	20.27	38.16
70N	17.52	23.65	44.52
80N	20.02	27.02	50.88
90N	22.52	30.4	57.24
100N	25.03	33.78	63.61

Figure 4. Vertical von mises stress bar graph

3.2 Strain analysis (strain)

Figure 5 (A), (B), and (C) show the results of the strain simulation that occurs. The R15 strain is 0.0308, the R30 design is 0.04441 and the R45 design is 0.0628. The value that occurs at a strain will always be directly proportional to the value of the stress that occurs. The greater the stress value, the greater the strain value. The normal strain that occurs is said to be dimensionless, so in a strain calculation it does not have area units. If a tensile stress is applied, the strain that occurs is also called a tensile strain, if a compressive stress is applied, the strain that occurs is also called a compressive strain [14].

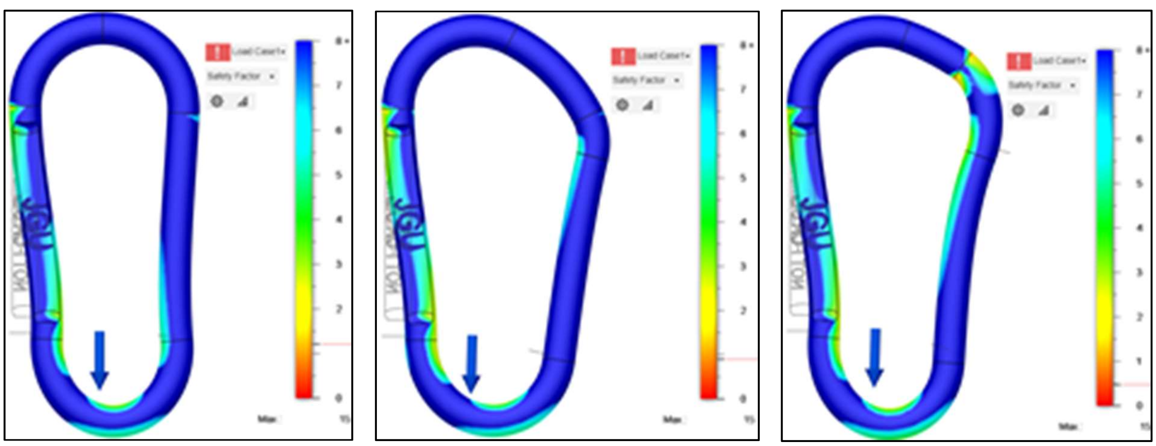


(A) (B) (C)

Figure 5. Strain for designs (A) R15, (B) R30, and (C) R45.

3.3 Factor of safety analysis

Figure 6 (A), (B) and (C) show the test surface reaction in simulating the factor of safety of the carabiner design. In order to meet product suitability standards, the factor of safety value obtained must be $\geqslant 4$ [16]. Design R15 safety load is 20 N, then design R30 is 20 N and Design R45 is 10 N.



(A) (B) (C)

Figure 6. Surface reaction factor of safety design (A) R15, (B) R30, and (C) R45.

Changes in the reaction on each product surface are caused by design changes made, the more parallel the shape of the curve of the stationary (fixed) part with the curve of the moving bottom, namely the loading part, resulting in a low stress distribution. Then the orange part on the surface of the test product is the part that experienced a very large stress reaction, while the blue part shows a low stress reaction or no stress reaction occurred. To see more clearly in Figure 7, the graph of the FoS that occurred.

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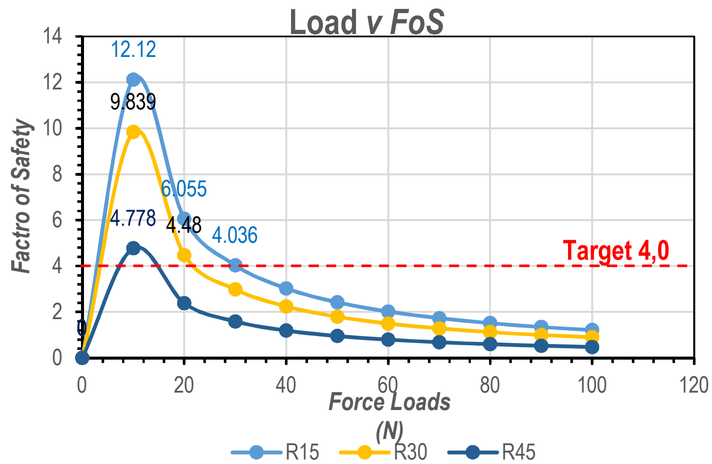

Figure 7. Vertical factor of safety graph

3.3 Validation of computational data results and analytical calculations

Design validation is used to determine the percentage difference between the results of computer computing calculations and the results of calculations using formulas for each design. The following is data from analytical calculations using formulas:

3.3.1 R15 design validation

a. Load 10 N

$$Sf = \frac{Yield\ Stress}{Calculated\ Stress}$$

$$Sf = \frac{30{,}4}{2{,}501}$$

$$Sf = 12{,}15$$

b. Load 20 N

$$Sf = \frac{Yield\ Stress}{Calculated\ Stress}$$

$$Sf = \frac{30{,}4}{5{,}004}$$

$$Sf = 6{,}07$$

c. Load 30 N

$$Sf = \frac{Yield\ Stress}{Calculated\ Stress}$$

$$Sf = \frac{30{,}4}{7{,}507}$$

$$Sf = 4{,}049$$

For more details, it can be seen in Table 2, the difference in factor of safety that occurs between computer calculation results, using analytical calculations with the formula:

Table 2. Validation of vertical safety factors of Design R15.

Load (N)	The value of fusion 360 computing	Formula calculation value	Difference	Errors (%)
10 N	12,12	12,15	0,03	1
20 N	6,055	6,07	0,015	1
30 N	4,036	4,049	0,013	1
40 N	3,027	3,036	0,009	1

Load (N)	The value of fusion 360 computing	Formula calculation value	Difference	Errors (%)
50 N	2,422	2,43	0,008	1
60 N	2,018	2,023	0,005	1
70 N	1,73	1,735	0,005	1
80 N	1,513	1,518	0,005	1
90 N	1,345	1,349	0,004	1
100 N	1,211	1,214	0,003	1

3.3.2 R30 design validation

a. Load 10 N

$$Sf = \frac{Yield\ Stress}{Calculated\ Stress}$$

$$Sf = \frac{30,4}{3,08}$$

$$Sf = 9,8$$

b. Load 20 N

$$Sf = \frac{Yield\ Stress}{Calculated\ Stress}$$

$$Sf = \frac{30,4}{6,763}$$

$$Sf = 4,5$$

c. Load 30 N

$$Sf = \frac{Yield\ Stress}{Calculated\ Stress}$$

$$Sf = \frac{30,4}{10,14}$$

$$Sf = 3$$

For more details, we can see the validation of calculations in Table 3, the difference in FoS that occurs between computer calculation results, using formula calculations:

Table 3. Validation of the vertical safety factor of the R30 design.

Load (N)	The Value of Fusion 360 Computing	Formula Calculation Value ($SF = Fu/Fi$)	Difference	Errors (%)
10 N	9,839	9,87	0,0311	1
20 N	4,48	4,49	0,050	1
30 N	2,98	2,99	0,01	1
40 N	2,242	2,248	0,0065	1
50 N	1,793	1,799	0,0069	1
60 N	1,495	1,499	0,0048	1
70 N	1,281	1,2854	0,0044	1
80 N	1,121	1,125	0,0041	1
90 N	0,9967	1	0,0032	1
100 N	0,897	0,899	0,0089	1

3.3.3 R45 design validation

a. Load 10 N

$$Sf = \frac{Yield\ Stress}{Calculated\ Stress}$$

$$Sf = \frac{30,4}{6,324}$$

$$Sf = 4{,}807$$

b. Load 20 N

$$Sf = \frac{Yield\ Stress}{Calculated\ Stress}$$

$$Sf = \frac{30{,}4}{12{,}7}$$

$$Sf = 2{,}39$$

c. Load 30 N

$$Sf = \frac{Yield\ Stress}{Calculated\ Stress}$$

$$Sf = \frac{30{,}4}{19{,}07}$$

$$Sf = 1{,}59$$

Table 4. Validation of the vertical safety factor of the R45 design.

Load (N)	The Value of Fusion 360 Computing	Formula calculation value ($SF = Fu/Fi$)	Difference	Errors (%)
10 N	4,778	4,807	0,0291	1
20 N	2,385	2,393	0,0087	1
30 N	1,589	1,594	0,0051	1
40 N	1,191	1,244	0,0534	1
50 N	0,953	0,956	0,0033	1
60 N	0,7941	0,796	0,0025	1
70 N	0,6806	0,682	0,0022	1
80 N	0,5955	0,597	0,0020	1
90 N	0,5293	0,531	0,0018	1
100 N	0,4764	0,477	0,0015	1

From the calculation and validation results in Table 4, there is a maximum error difference of 1%, the error percentage level obtained is still below the maximum allowable error limit, namely 5% of the error difference that occurs.

3 CONCLUSION

The different shapes in each carabiner design cause differences in the tension distribution that occurs. The R15 design has a maximum stress value at a load of 100N, namely 25.03 MPa, then the R30 design is 33.78 MPa, and the R45 design is 63.61 MPa. The R30 design has an advantage in the gate opening range of 26.07 mm, a difference of 6.56mm compared to the R15 design. The vertical loading direction has a product safety level of 4.0 achieved at a load of 20N for the R15 and R30 designs. Meanwhile, the axial load is only able to withstand 5 N to reach the target of 4.0. The difference in the factor of safety calculation of 4.0 between computer computing results and analytical calculation results using a formula is 1%, this value is still reasonable because it is still below the maximum tolerance value of 5%.

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REFERENCE

[1] Sari, N. H., & Suteja, S. T. (2021). *Polimer Termoset.* Deepublish.

[2] Huda, M. (2017). *Analisa Kekuatan Polimer Thermoplastic Polypropilen Dengan Pengisi Black Carbon (Abu Dasar Batu Bara)* (Doctoral dissertation, Untag Surabaya).

[3] dos Prazeres Rodrigues, R. C., Araújo, C. R., & Ennes, M. (2014). Mosquetões HMS: um estudo coMParativo de Usabilidade. *Cadernos UniFOA*, 9(1 (Esp.)), 67-81.
[4] Ennes, M., Rodrigues, R. C. P., & Araújo, C. R. (2012). Mosquetões Hms: um estudo coMParativo de usabilidade. *Cadernos UniFOA*, 7(1 Esp), 338-338.
[5] Ismawanto, A., Syarief, A., & Isworo, H. (2014). "Simulasi kekuatan material pada *carabiner* dengan variasi geometri*". Jurnal Ilmiah Teknik Mesin Unlam, 3(1), 52-57.*
[6] Domininghaus, H. (1979). Plastics in mining. *Gummi, Asbest, Kunstst.;(Germany, Federal Republic of), 32(3).*
[7] Ismawanto, A., Syarief, A., & Isworo, H. (2014). "Simulasi kekuatan material pada *carabiner* dengan variasi geometri". *Jurnal Ilmiah Teknik Mesin Unlam, 3(1), 52-57.*
[8] Irsat, M. M. (2018). *Tingkat Kekuatan Carabiner Dengan Beberapa Bentuk Variasi Dari Bahan AL 6061 Dengan Desain Triangel, Pentagon, Box, Butterfly Wings, Kite* (Doctoral dissertation, UNIVERSITAS 17 AGUSTUS 1945).
[9] Kotler, P. & Armstrong, G. (2012), *Prinsip- Prinsip Pemasaran* Edisi 12 penerbit Erlangga.
[10] Kotler, P. & Keller, K.L. (2012), *Manajemen Pemasaran Jilid I* Edisi ke 12. Jakarta: Erlangga.
[11] Kotler, Philip dan Kevin Lane Keller. (2017). *Manajemen Pemasaran. Edisi 1*.Alih bahasa: Bob sabran, MM. Jakarta :Erlangga
[12] Souisa, M. (2011). Analisis Modulus Elastisitas dan Angka Poisson Bahan Dengan Uji Tarik. *BAREKENG: Jurnal Ilmu Matematika dan Terapan, 5(2), 9-14.*
[13] Khoiriah, S. (2020). Desain dan Analisis Kekuatan pada Ladder Frame Chassis Kendaraan Hybrid Elektrik–Pneumatik Menggunakan Software Autodesk Inventor Profesional 2017. *Universitas Negeri Semarang.*
[14] Isworo, F. (2018). Mekanika Kekuatan Material I (Hmkk319). *Buku Ajar*, 19-22.
[15] Sofyan, D., Gamayel, A., & Zaenudin, M. (2023). SIMULASI UJI IMPACT PADA DESAIN VELG BERBAHAN ASTM A299 DENGAN DIAMETER 15 INCH DENGAN STANDARD UJI SAE J175. *Scientific Journal of Mechanical Engineering Kinematika*, *8*(1), 85-93.
[16] Salimin, Samhuddin, dan I. Adha. 2018. Perancangan dan Analisa Simulasi Pembebanan Chassis Sepeda Wisata Untuk Dua PenuMPang Menggunakan Software Autodesk Inventor 2017. *Jurnal Ilmiah Mahasiswa Teknik Mesin 3(3): 1-12.*