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Research article

Thermal Stress Analysis for Barrel and Screw Component in The Plastic Waste Machine Using Finite Element Method

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A B S T R A C T

Plastic waste causes negative impacts for environmental such as air pollution, water pollution, and others. To solve this problem, a plastic processing machine was made. Barrels and screws are the most important components of this machine. Aims in this study to find maximum thermal stress for the barrel and screw component in the plastic waste machinery with temperatures operation 260 ^{0}C and variation material. Finite element method are used to simulate and show that the results for the barrel using alloy steel has a maximum von Mises stress of 618,292 MPa. For displacement, this alloy steel material also has a maximum displacement of 0.612 mm. For the screw material used by using AISI 4340 Steel has a maximum von Mises stress of 849.997 MPa and the maximum displacement of 0.673 mm. It can be said that this material is still safe when used for barrels and screws component in the plastic waste machine processing.

1. INTRODUCTION

Plastic waste is the most discarded waste by the community because many people, individuals, shops, and large companies use plastic for daily needs. The existence of this waste causes negative environmental impacts such as air pollution, water pollution, soil pollution, and the worst global warming. One way to overcome this problem is to make a machine or plastic processing tool.

In plastic processing, barrels and screws play an important role in injecting plastic raw materials and smoothing the process. Plastic processing exposes raw materials to high temperatures [1], [2], [3].

Plastic Processing Machine is the process by which plastic ore is heated to a certain temperature, converted from solid to liquid, and injected into a mold. Plastic processing machinery is one of the most important tools in the plastic processing industry. To avoid damage to the barrel and screw, it is necessary to analyze to determine the voltage distribution before conducting experiments. One of them is a numerical method using SolidWorks software, to reduce component failures. Therefore, it is very important to determine the optimal temperature and material for each type of plastic waste used as raw material [4], [5], [6], [7], [8].

2. METHOD

Research method is an important part of research to find out how we do this research. This research uses the finite element method through SolidWorks 2016 software, which will carry out a testing process by simulating materials with optimal temperature variables. For variables to be used there are

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independent variables, bound variables, and control variables.

1. Independent Variable
   The independent variable is the variable that will be used is make differences in research to obtain optimal results in its use and functionality.
   a) Barrel
      There are several materials used for barrels, as can be seen in Table 1.

Table 1. Barrel Material

No	Variable	Specificationa	
		Modulus of Elasticity N/mm^2	Yield Strength N/mm^2
1	AISI 316 Stainless Steel	192999.9974	172.3689323
2	Alloy Steel	210000	620.422

   b) Screw
      There are several variables used for screws which can be seen in the Table 2

Table 2. Screw Material

No	Variable	Specificationa	
		Modulus of Elasticity N/mm^2	Yield Strength N/mm^2
1	AISI 4340	205000	710
2	AISI 1020	200000	351.571

2. Control Variable
   Control variables are variables that are made equal in research. For the control variable, this study used a temperature of 260^o C with a thickness of 7.14 mm from the dimensions used for barrels. The diameter of 23 shafts and the diameter of 40 iron plates are circular from the dimensions used by the screw and will be analyzed using SolidWorks Software 2016
3. Bound Variables
   The bound variables are variables that will be observed at the time of research. The variables to be observed in this study are the results of the analysis of Von Mises Stress, Displacement, and Safety Factors.

2.1. Tools and Materials

Tools and materials used in the study:

1. Computer/Laptop Device
2. SolidWorks Software 2016

2.2. Flow chart

A flow chart is a diagram to illustrate a workflow that is usually widely used and is certainly always present in conducting research. The flow diagram of this study can be seen in Fig.1.

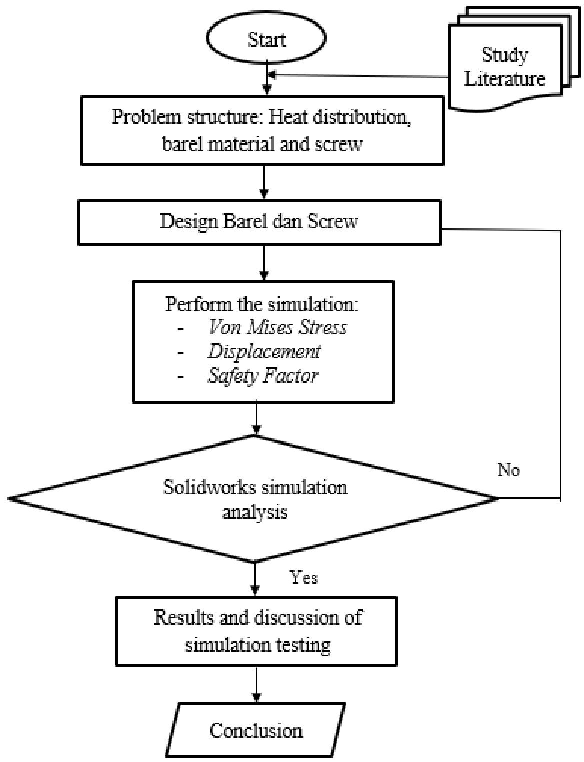

Figure 1. Research flow chart

This research flow diagram by reading the study literature solves the existing problem, namely heat distribution with the right and optimal temperature and material for barrels and screws. By making the barrel and screw designs (as shown in Fig.2), von Mises stress, displacement, and safety factor simulations were carried out. After the simulation, an analysis of the data was obtained and conclusions were drawn from the research that had been done.

2.3. Data Analysis Techniques

This research was conducted with SolidWorks 2016 software simulation using the concept of finite element method to analyse the strength of a design and material. This method is very effective and efficient in finding out the von Mises, displacement, and safety factors of the image that has been designed.

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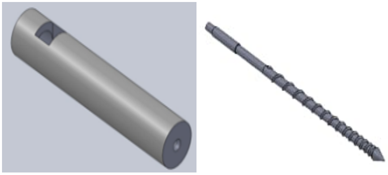

Figure 2. Barrel and Screw

3. RESULTS AND DISCUSSION

3.1. Analysis of Physical Properties of Materials

The process carried out in this study uses SolidWorks simulations that obtain physical properties from the material. The physical properties of the AISI 316 Stainless Steel (SS) and Alloy Steel barrel material can be seen in Table 3.

Table 3. Physical properties of barrel materials

Name	AISI 316 Stainless Steel (SS)		
No	Property	Value	Units
1	Elastic Modulus	192999.9974	N/mm^2
2	Poisson's Ratio	0.27	N/A
3	Tensile Strength	580.0000008	N/mm^2
4	Yield Strength	172.3689323	N/mm^2
5	Tangent Modulus		N/mm^2
6	Thermal Expansion Coefficient	1.6e-005	/k
7	Mass Density	8000	Kg/m^3
8	Hardening Factor	0.85	N/A
Name	Alloy Steel		
No	Property	Value	Units
1	Elastic Modulus	210000	N/mm^2
2	Poisson's Ratio	0.28	N/A
3	Shear Modulus	79000	N/mm^2
4	Mass Density	7700	Kg/m^3
5	Tensile Strength	723.8256	N/mm^2
6	Compressive Strength		N/mm^2
7	Yield Strength	620.422	N/mm^2
8	Thermal Expansion Coefficient	1.3e-005	/K
9	Thermal Conductivity	50	W/(m.K)
10	Specific Heat	460	J/(kg.K)

The physical properties of screw materials type AISI 4340 Steel and AISI 1020 can be seen in Table 4.

Table 4. Physical Properties of Screw Material

Name	AISI 4340 Steel		
No	Property	Value	Units
1	Elastic Modulus	205000	N/mm^2
2	Poisson's Ratio	0.32	N/A
3	Shear Modulus	80000	N/mm^2
4	Mass Density	7850	Kg/m^3
5	Tensile Strength	1110	N/mm^2
6	Compressive Strength		N/mm^2
7	Yield Strength	710	N/mm^2
8	Thermal Expansion Coefficient	1.23e-005	/K
9	Thermal Conductivity	44.5	W/(m.K)
10	Specific Heat	475	J/(kg.K)
Name	AISI 1020		
No	Property	Value	Units
1	Elastic Modulus	200000	N/mm^2
2	Poisson's Ratio	0.29	N/A
3	Shear Modulus	77000	N/mm^2
4	Mass Density	7900	Kg/m^3
5	Tensile Strength	420.507	N/mm^2
6	Compressive Strength		N/mm^2
7	Yield Strength	351.571	N/mm^2
8	Thermal Expansion Coefficient	1.5e-005	/K
9	Thermal Conductivity	47	W/(m.K)
10	Specific Heat	420	J/(kg.K)

3.2. Result of Maximum Stress Von Mises

Von Mises Stress is one of the important concepts in design. Von Mises stress is commonly used to evaluate the strength and durability of a material when applied a force called shock load or temperature. Simulation results through SolidWorks Software using static analysis. Static analysis is one of the analytical techniques to determine the stress of materials and structures that experience static or dynamic forces. Analysis uses a method called the finite element method to determine the design and also the material designed is said to be safe or unsafe. The stress must be reached and not exceed the yield strength, if it exceeds the yield point then the material cannot return to normal.

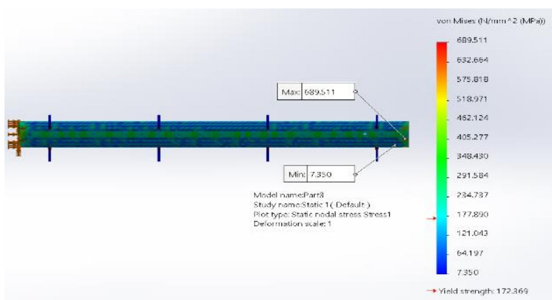

Figure 3. Von Mises Stress On AISI 316 Stainless Steel (SS) Barrel

By simulating barrels component using AISI 316 Stainless Steel (SS) Material with a thickness of 7.14 mm and given a temperature load of 260 0 C, a minimum Von Mises stress value of 7,350 MPa was obtained while Von Mises stress was a maximum of 689,511 MPa with a Yield Strength of 172,368 MPa as shown in Fig. 3.

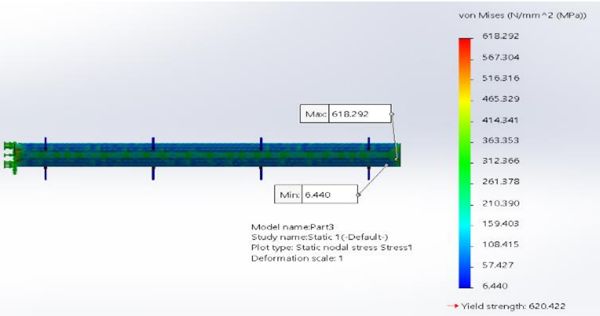

Figure 4. Von Mises Stress On Alloy Steel Barrels

The simulating barrels on Alloy Steel Material with a material thickness of 7.14 mm and given a temperature load of 260 0 C, a minimum von Mises stress value of 6,440 MPa was obtained while von Mises stress was a maximum of 618,292 MPa with a Yield Strength of 620,422 MPa as shown in Fig. 4.

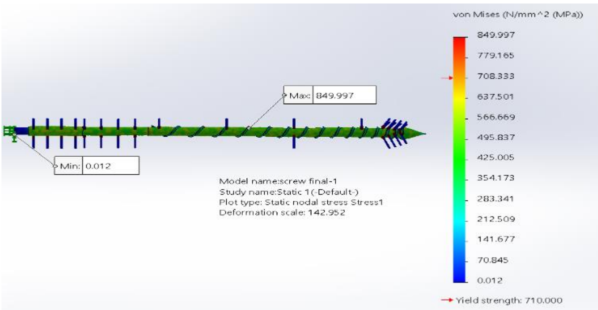

Figure 5. Von Mises Stress On AISI 4340 Steel Screw

For screw simulations on AISI 4340 Steel Material which was given a temperature load of 260 0 C, a minimum von Mises stress value of 0.012 MPa was obtained while the maximum von Mises stress was 849,997 MPa with a Yield Strength of 710,000 MPa (see Fig. 5).

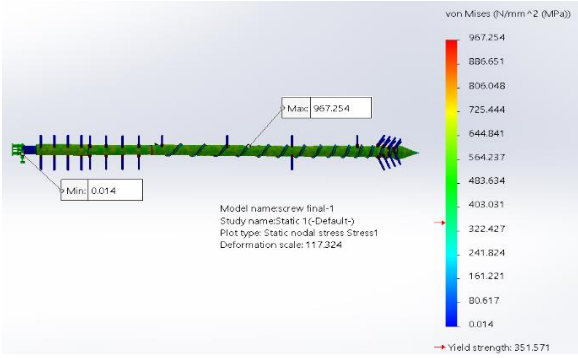

Figure 6. Von Mises Stress On AISI 1020 Screw

For screw AISI 1020 Material which was given a temperature load of 260 0 C, a minimum von Mises stress value of 0.014 MPa was obtained while the maximum von Mises stress was 967,254 MPa with a Yield Strength of 351,571 MPa as shown in Fig. 6.

3.3. Displacement

Displacement has the advantage of showing defects through scale representation with certain conditions. The use of displacement to see changes in shape from the original form.

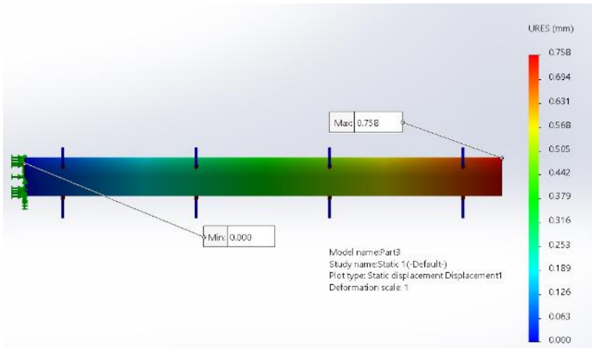

Figure 7. Displacement on AISI 316 stainless steel (SS) barrel

For barrels AISI 316 Stainless Steel (SS) Material with a material thickness of 7.14 mm and given a temperature load of 260 0 C, a minimum Displacement value of 0.000 mm was obtained while the maximum Displacement value was 0.758 mm. Barrels on Alloy Steel Material with a material thickness of 7.14 mm and given a temperature load of 260 0 C, a minimum Displacement value of 0.000 mm was obtained while the maximum Displacement value was 0.616 mm as shown in Fig. 7-8.

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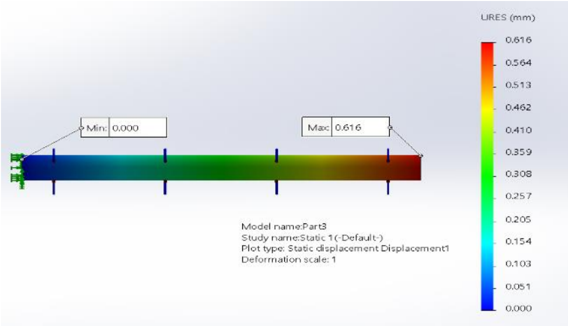

Figure 8. Displacement on Alloy Steel Barrels

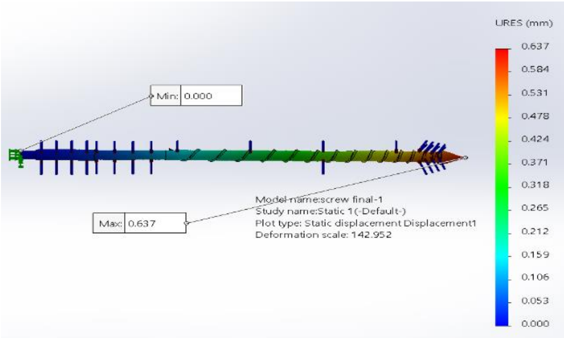

Figure 9. Displacement on AISI 4340 Steel Screw

The screw AISI 4340 Steel Material which was given a temperature load of 260 0 C, a minimum Displacement value of 0.000 mm was obtained while the maximum Displacement was 0.637 mm as shown in Fig. 9.

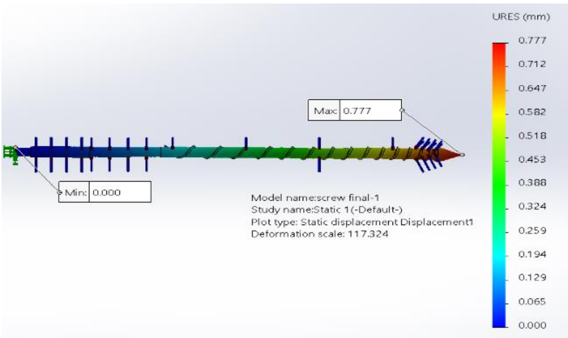

Figure 10. Displacement on AISI 1020 Screw

And the screw AISI 1020 Material which was given a temperature load of 260 0 C, a minimum Displacement value of 0.000 mm was obtained while the maximum Displacement was 0.637 mm as shown in Fig. 10.

3.4. *Safety Factor (FOS)*

Safety Factor is one of the assessments to find out whether the design made is said to be safe or unsafe. To know whether the design is safe or not note that the security value must be more than 1 (Fos>1) so that it can be said that the design is safe.

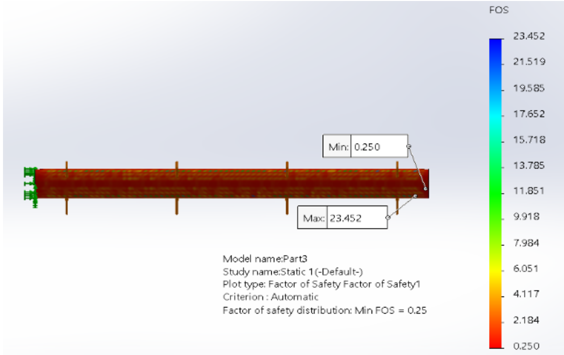

Figure 11. Safety Factor On AISI 316 Stainless Steel (SS) Barrel

The barrels on AISI 316 Stainless Steel (SS) Material with a material thickness of 7.14 mm and given a temperature load of 260 0 C, a minimum Safety Factor value of 0.250 was obtained while the maximum Safety Factor value was 23.452 as shown in Fig. 11.

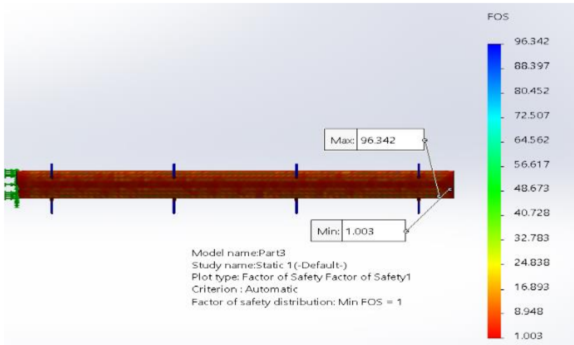

Figure 12. Safety Factor on Alloy Steel Barrels

For barrels on Alloy Steel Material with a material thickness of 7.14 mm and given a temperature load of 260 0 C, a minimum Safety Factor value of 1,003 was obtained while the maximum Safety Factor value was 96,342 as shown in Fig. 12.

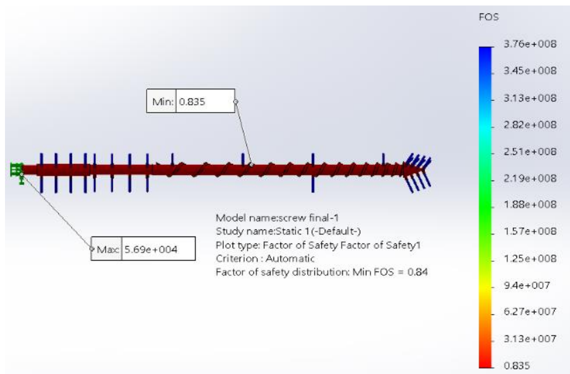

Figure 13. Safety Factor on AISI 4340 Steel Screw

For screw on AISI 4340 Steel Material which was given a temperature load of 260 0 C, a minimum Safety Factor value of 0.835 was obtained while the maximum Safety Factor was 5.69e + 004 as shown in Fig. 13.

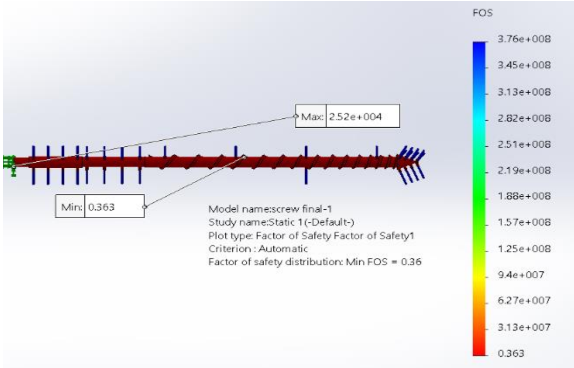

Figure 14. Safety Factor on AISI 1020 Screw

The screw AISI 1020 Material which was given a temperature load of 260 0 C, a minimum Safety Factor value of 0.363 was obtained while the maximum Safety Factor was 2.52e + 004 as shown in Fig. 14.

Based on the simulation results with different materials, namely for barrels using AISI 316 Stainless Steel (SS) and Alloy Steel. So obtained values from Von Mises Stress, Displacement, and Safety Factor simulation data can be seen in Table 3.

Table 5. Barrel Analysis Results

Result Simulation	Description	Variable	
		AISI 316	Alloy Steel
Von Mises (MPa)	Min	7.350	6.440
	Max	689.511	618.292
Displacement (mm)	Min	0.000	0.000
	Max	0.758	0.612
Safety Factor	Min	0.250	1.003
	Max	23.452	96.342

Based on the simulation results with different materials, namely for screws using AISI 4340 Steel and AISI 1020. So obtained values from Von Mises Stress, Displacement, and Safety Factor simulation data can be seen in Table 6.

Table 6. Screw Analysis Results

Von Mises (MPa)	Min	0.012	0.014
	Max	849.997	967.254
Displacement (mm)	Min	0.000	0.000
	Max	0.673	0.777
Safety Factor	Min	0.835	0.363
	Max	5.69+004	2.52e+004

From the complete data in Tables 5 and 6 after simulating barrels and screws with several materials used in simulations at SolidWorks 2016, the barrels to be used are alloy steel types because these materials have a minimum von Mises stress of 6,440 MPa and a maximum von Mises stress of 618,292 MPa which does not pass the yield strength of 620,422 MPa. For displacement, this alloy steel material also has a minimum displacement of 0.000 mm and a maximum displacement of 0.612 mm. With a safety factor achieved up to number 1 which means this material is safe when used when given a temperature of 260 0 C. While the AISI 316 Stainless Steel (SS) material has a minimum von Mises stress of 7,350 MPa and a maximum von Mises stress of 689,511 MPa which exceeds the yield strength of 172,368 MPa. The minimum displacement is 0.000 mm and the maximum displacement is 0.758 mm longer than alloy steel material. The safety factor achieved is also only 0.25 not up to number 1 which means this material cannot be said to be safe.

For the screw that will be used AISI 4340 Steel material because the material has a minimum von Mises stress of 0.012 MPa and a maximum von Mises stress of 849.997 MPa which is not far from the yield strength of 710,000 MPa. For displacement, this alloy steel material also has a minimum displacement of 0.000 mm and a maximum displacement of 0.673 mm. With a safety factor that is achieved almost reaches number 1, which is 0.83 when used when given a temperature of 260 0 C. While the AISI 1020 material) has a minimum von Mises stress of 0.014 MPa and a maximum von Mises stress of 967.254 MPa which exceeds the yield strength of 351.571 MPa. The minimum displacement is 0.000 mm and the maximum displacement is 0.777 mm longer than AISI 4340 Steel material. The safety factor achieved is also only 0.36 further than number 1 which means better AISI 4340 Steel material.

4. CONCLUSION

The barrel to be used is an alloy steel type because the material has a minimum von Mises stress of 6,440 MPa and a maximum von Mises stress of 618,292 MPa which does not pass the yield strength of 620,422 MPa. For displacement, this alloy steel material also has a minimum displacement of 0.000 mm and a maximum displacement of 0.612 mm. With a safety factor achieved up to number 1 which means this material is safe when used when given a temperature of 260 0 C.

For the screw that will be used AISI 4340 Steel material because the material has a minimum von Mises stress of 0.012 MPa and a maximum von Mises stress of 849.997 MPa which is not far from the yield strength of 710,000 MPa. For displacement, this alloy steel material also has a minimum displacement of 0.000 mm and a maximum displacement of 0.673 mm. With a safety factor that is achieved almost reaches number 1, which is 0.83 when used when given a temperature of 260 0 C.

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