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Improvement of Blower Impeller Design Using Finite Element Analysis Method

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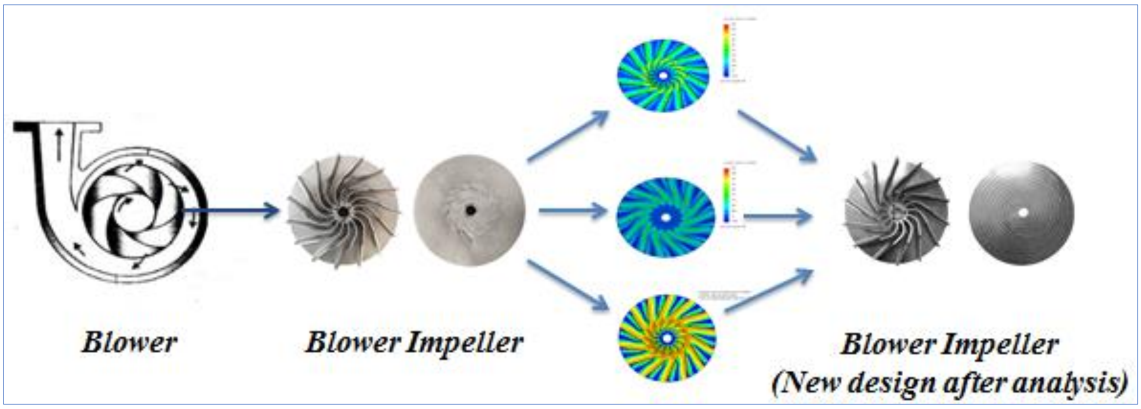
Abstract

Blowers are widely used in industrial and commercial applications such as degassing, textile machinery, and treatment plants. There are many different parameters in designing blower impellers with extensive application areas, and therefore it is necessary to use analysis programs based on the finite element method to achieve accurate results. In this study, the blower designed by Solidworks was analyzed with Solidworks Simulation in order to eliminate the damage to the blowers used in fabric cutting machines and to improve the design.According to damage type, focused on the centrifugal forces as cause of damage also blower geometrical parameters and material choice were examined.The results obtained were compared with the experimental results, and the blower was improved with the analysis program. In line with the analyzes and experimental results obtained, a blower design with a safety factor of 1.5 and serviceable were carried out using aluminum 7075 T6 material.



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1 INTRODUCTION

Blower systems are defined as installation elements that provide the transfer of emissive air at high flow or low pressure by rotating the fan with the force it receives from the engine [1,2]. Blowers used to transport or vacuum the air find application in industrial and commercial areas. Food washing [3], suction equipment [4], degassing [5], textile machinery [6], etc. blowers are used in many fields; they are divided into five groups positive displacement blowers [7], centrifugal blowers [8], multistage centrifugal blowers [9], high-speed blowers [10], and regenerative blowers [11]. Difficult working conditions such as high speed [12] and vibration [13] can be encountered in all the specified blower types, and studies are being carried out on the design of the blower to cope with all these adverse conditions. Although CFD analysis is necessary to design the blower wheel, it is not sufficient on its own. During operation, blowers are exposed to different values and varying loads, and to provide the desired performance and life, static and dynamic analyzes should be done as well as CFD analysis [14,15]. In blowers to be designed with the specified analyzes (CFD, static and dynamic analyses), attention should be paid to the design of the impeller blades, and the impeller blades must be light and robust. The high speed of the blowers causes the formation of high centrifugal loads. In this context, the material and dimensions of the blowers have critical importance in obtaining the desired design. There are many types of materials to increase blower performance, and various aluminum alloys and composite materials are used in industrial applications [16,17]. In literature research, the most popular materials used in blower design are 6000 series and 7000 series aluminum alloys with high durability, lower weight and lower cost advantages compared to composite materials [18,19].

There are many different parameters (material, blade, etc.) in the design of the blower and to make the necessary calculations in the design, a computer-aided numerical analysis method called finite element analysis (FEA) should be used. There are many different analysis software based on the FEA method, and Solidworks Simulation is one of the analysis programs used in this field. Solidworks Simulation can obtain accuracy results besides that crucial specification it is lower cost than other commercial analysis programs [20].

In this study, the blower design was carried out using SolidWorks to prevent damage to the blowers used in fabric cutting machines and to improve the design, and the necessary calculations were analyzed using the Solidworks Simulation program. The obtained analysis results were compared with the experimental results and the necessary improvements were made with Solidworks Simulation.

2 MATERIAL AND METHOD

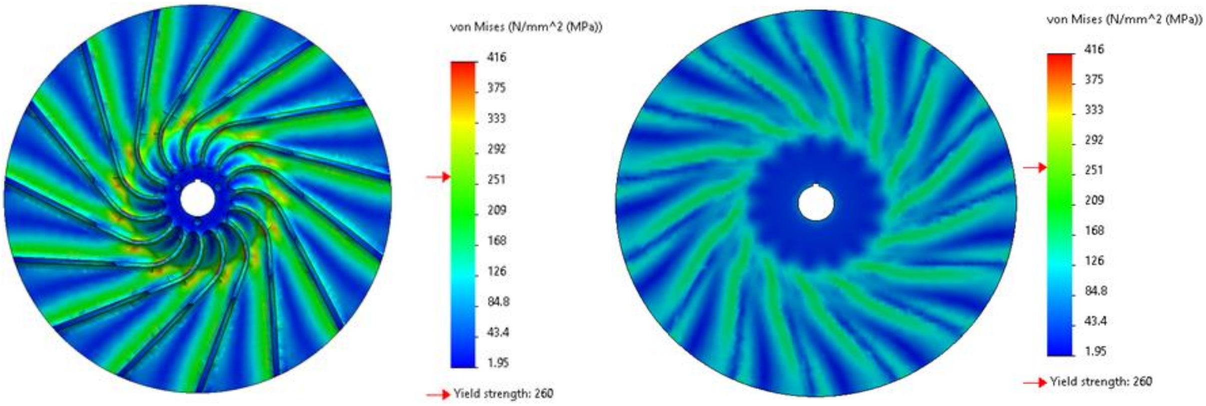
The aim of this study, which examines a blower used in the industry, is to identify the blower used by Solidworks Simulation and make the necessary analyses to prevent possible damages (Figure 1). The operating conditions of the system are given in Table 1.

Figure1. Damaged Blower Impeller

Table 1. Working Conditions

P_{motor} (kW)	30
n_{shaft} (rpm)	24000
m_{shaft} (Nm)	12
$T_{environment}$ (°C)	150

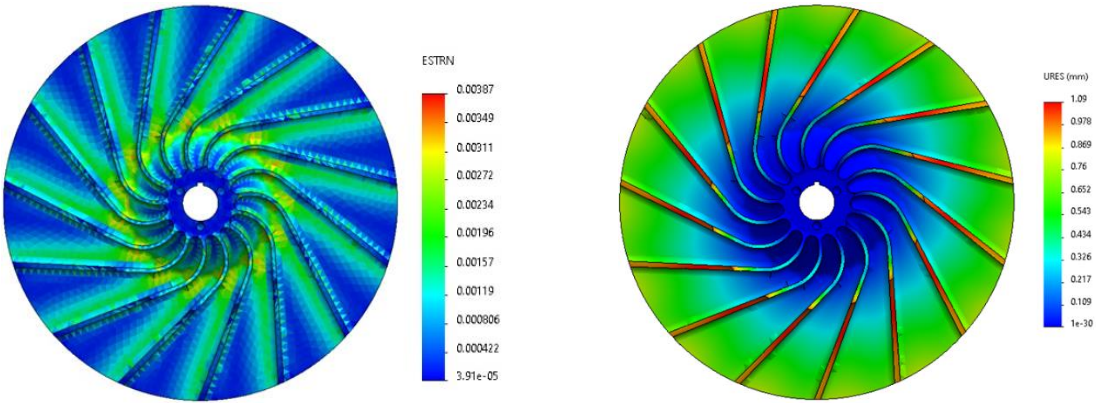
The blower was analyzed with Solidworks Simulation to determine the damages and the relevant results are given in Figure 2(a,b), Figure 3(a,b), Figure 4. The simulation results show that the blower will be damaged under the operating conditions specified in Table 1, and the experimental results confirm the simulation results. According to the simulation results, the safety factor value of the blower is below 1, and this value shows that the blower will not exhibit the desired working life under operating conditions. The blower is under high centrifugal loads during operation, and according to simulation studies, the main cause of damage is a high speed and weight. In the analysis, to effect of centrifugal force on impeller, the model was fixed in the center of it and applied 24 000 rpm centrifugal velocity . The results obtained from the simulation studies, it has been seen that the corners of the blower blades are critical places. The high stresses occurring in these places also showed that the damage occurred at the corners of the blower blades in the test results.



(a) (b)

Figure 2 (a, b). Stresses of Damaged Blower Impeller

As shown in Figure 2 (a, b) maximum von mises stress value is 416 MPa and this stress value is much higher than material yield strength value. According to plastic deformation criteria maximum von mises stress value must be lower than material yield strength value.



(a) (b)

Figure 3 (a) Strain and **(b)** Deformation of Damaged Blower Impeller

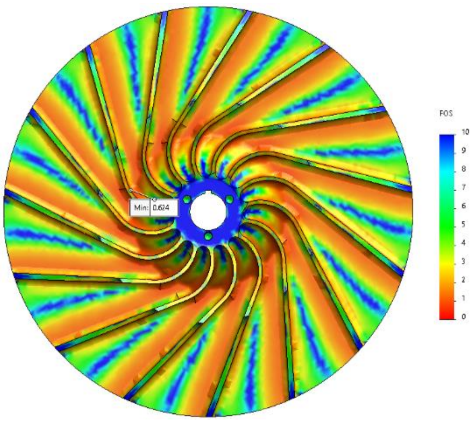


Figure 4. Safety Factor of Damaged Blower Impeller

According to analysis result, damaged blower impeller has 0.62 safety factor. This value is too low to obtain desired working life.

Blowers are rotating machines and centrifugal forces occur in these machines (Figure 5). Centrifugal forces are the main causes of damage to blower wheels. Speed, mass and radius of the center of rotation are the parameters of the centrifugal force, and especially speed and mass play an important role in the damage to the blower wheel examined within the scope of the study. The centrifugal force equation is presented in Equation 1 [21].

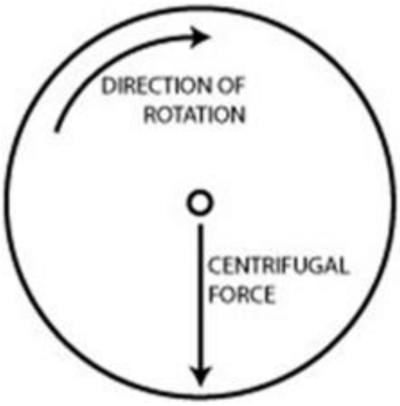


Figure 5. Centrifugal Force

$$F{:}m.r.\omega^2 \quad (1)$$

F: Centrifugal force (N)
M: Mass of rotation part (kg)
ω : Angular velocity (rad/sec)
r: Rotation radius (m)

To solve the problem under the specified operating conditions, it is necessary to increase the thickness of the blower blades. At the same time, another solution to the problem is to increase the radius value of the blades that intersect with the flat surface of the blower, and because increasing thicknesses will cause weight gain, there will be an increase in centrifugal loads. Therefore, the increase in blade thickness plays a critical role in solving the problem. An increase in the radius value can be considered as another solution. However, the radius value should be taken into account for production restrictions and it was determined that the most appropriate solution was to increase the blade thicknesses.

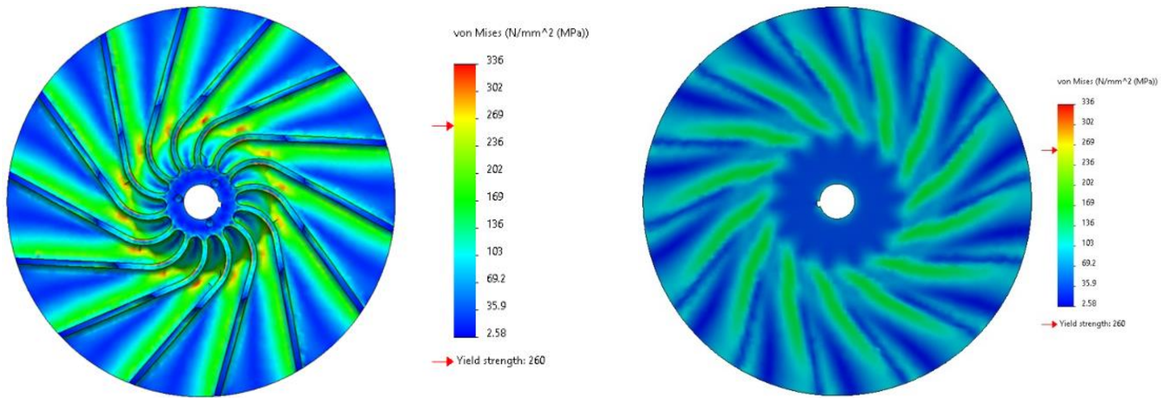
The properties of the materials used in the blower impeller design are given in Table 2.

Table 2. Material Properties [22]

	Al Alloy 6082 T6	Al Alloy 7075 T6
Density	2.70 g/cc	2.81 g/cc
Modulus of Elasticity	71 GPa	71.7 GPa
Poisson's Ratio	0.33	0.33
Tensile Strength, Ultimate	310 MPa	572 MPa
Tensile Strength, Yield	260 MPa	503 MPa
Hardness, Vicker	95	175
Elongation at Break	10 %	9 %

For Case 1

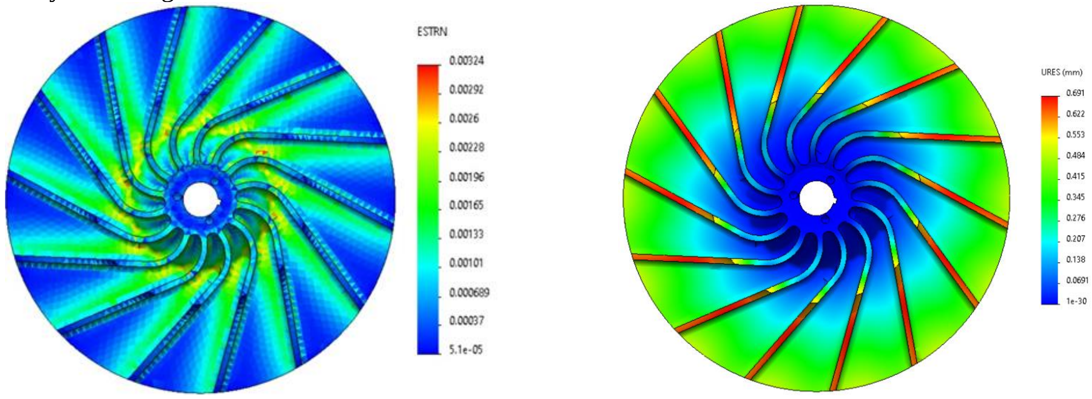
The thickness of the blower flat surface and blades has been increased. The simulation results of the first case are presented in Figure 6(a, b), Figure 7(a, b) and Figure 8. The simulation results showed that increasing the thicknesses had a positive effect to reduce the maximum von Mises Stress. The maximum stress concentration is at the corners of the blades and the safety factor value of the improved design was found to be 0.77.



(a) (b)

Figure 6. (a, b) Stresses of Blower Impeller in Case 1

As shown in Figure 6 (a, b) maximum von mises stress value is 336 MPa and this stress value is higher than material yield strength value.



(a) (b)

Figure 7. (a) Strain and (b) Deformation of Blower Impeller in Case 1

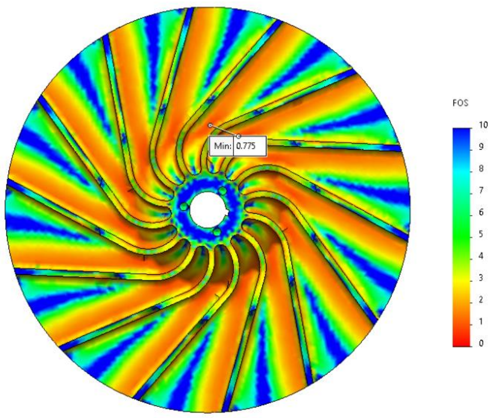


Figure 8. Safety Factor of Blower Impeller in Case 1

According to analysis result in Case 1, blower impeller has 0.77 safety factor. This value is not enough to obtain desired working life.

For Case 2

A second way to solve the problem is to use suitable materials. Aluminum alloy 6082 T6 was used in the previous design, and the experimental results and simulation results showed that the yield stress value of this material is not sufficient. For this reason, aluminum alloy 7075 T6 material is used in the new design. The properties of aluminum alloy 7075 T6 material are presented in Table 2. Here the aim of the new design is to overcome the damage problem without increasing the weight of the blower. The new simulation results are shown below (Figure 9, Figure 10(a,b) and Figure 11(a,b) and Figure 12).

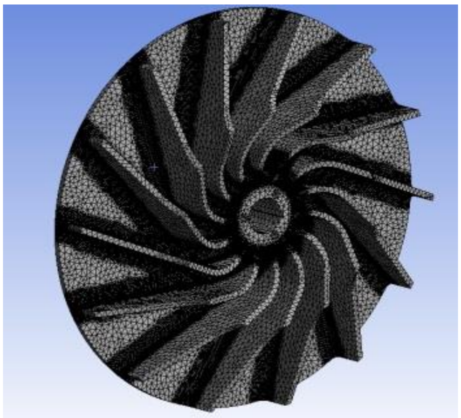
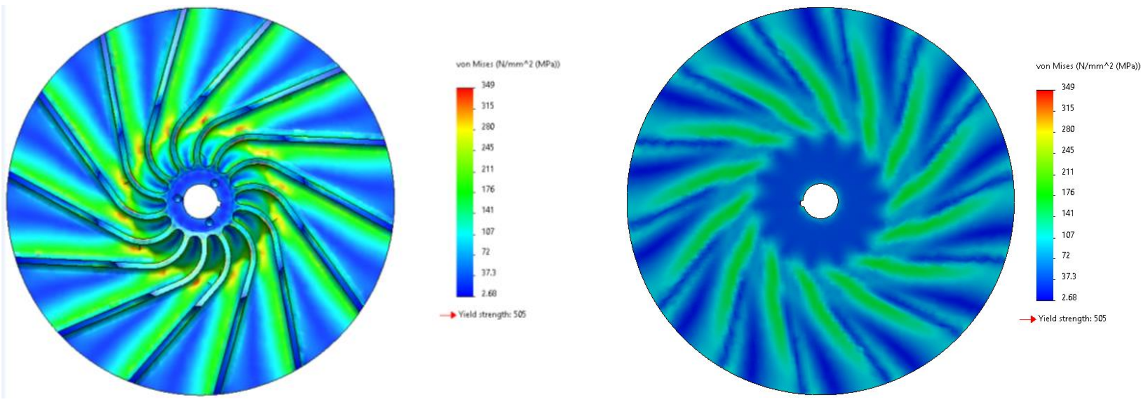


Figure 9. Mesh Image of Blower Impeller in Case 2

Table 3. Mesh properties of Case 2

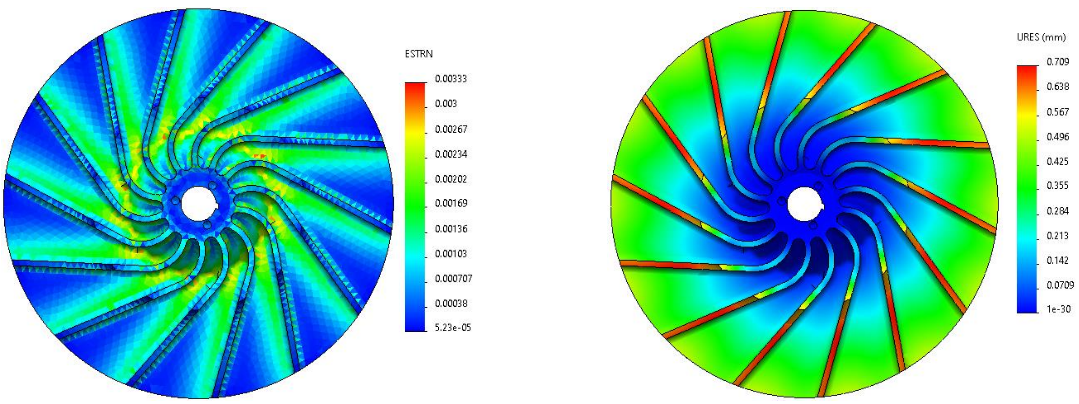
Element Type	Tetrahedrons
Elements	2337148
Nodes	3359169
Maximum Elemet Size	3.7 mm
Average Aspect Ratio	1.91
Average Skewness	0.26
Average Jacobian Ratio	0.99



(a) (b)

Figure 10. (a, b) Stresses of Blower Impeller in Case 2

As shown in Figure 10 (a, b) maximum von mises stress value is 349 MPa and this value is lower than material yield strength value that used in the analysis.



(a) (b)

Figure 11. (a) Strain and (b) Deformation of Blower Impeller in Case 2

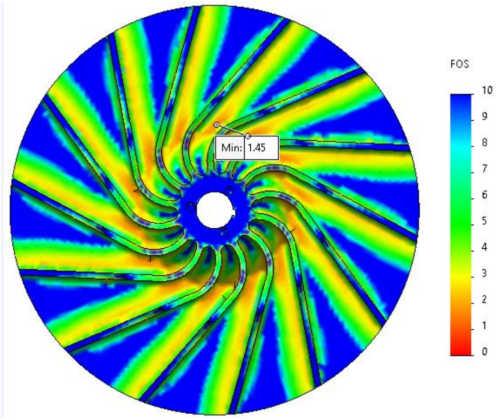


Figure 12. Safety Factor of Blower Impeller in Case 2

According to analysis result in Case 2, blower impeller has 1.45 safety factor. This value is enough to obtain desired working life.

3 RESULTS

Blower impeller has almost constant operation conditions. Therefore higher safety factor value is not necessary and experimental results are prove this approach[23]. According to this study, the new simulation results obtained show that aluminum 7075 T6 material is suitable for this design, and the safety factor value of the new blower is 1.45 and this value is sufficient for the operating conditions. Although the new material has a higher maximum von mises stress value, it is more resistant to centrifugal loads. The reason for the higher stresses here is due to the material density. The increased weight value is neglected for this density value. As a result of experimental studies and simulation studies, it has been seen that the new design is suitable for the specified working conditions. According to the experimental results obtained, it is seen that the new design is durable enough to overcome centrifugal loads and as a result, the new design works successfully. The redesigned blower is shown in Figure 13. The results obtained from the new design are given in Table 4. As seen in Table 4, the safety factor, blower impeller weight , maximum stress (MPa), strain ve deformation values of the blower designed according to Case 2 (final design) gave very good results compared to the damaged design and Case 1.

Table 4. Design Results

	Maximum Stress (MPa)	Blower Impeller Weight (kg)	Yield Strength (MPa)	Safety Factor	Strain	Deformation (mm)
Damaged Design	416	0,57	260	0,62	0.00387	1.09
Case 1	336	0,64	260	0,77	0.00324	0.691
Case 2 (Final Design)	349	0,69	503	1,45	0.00333	0.709

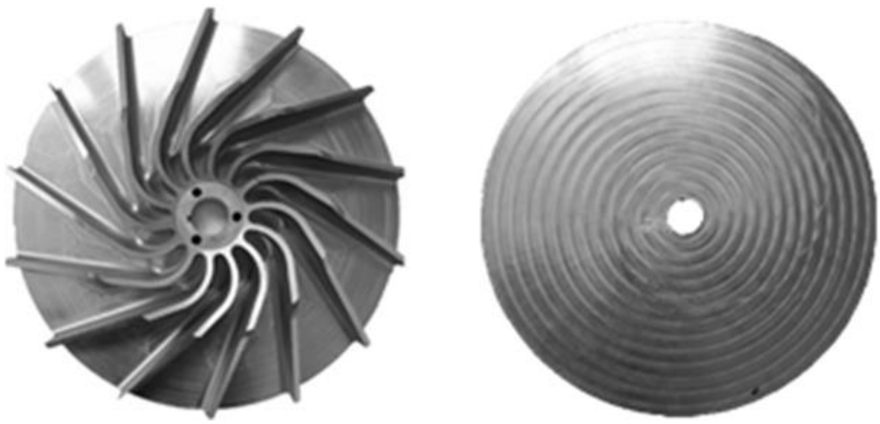


Figure 13. Redesigned Blower Impeller

4 CONCLUSION

Blowers are widely used machines in different industrial applications, and in some applications, the operating conditions can be difficult to achieve the desired performance and operating life. In such cases, the blower design can be complex and have different parameters. Finite element method based analysis software is useful to overcome such problems and Solidworks Simulation offers powerful solutions for complex problems such as blower design.

In this study, the damaged fan wheel was analyzed and redesigned using Solidworks Simulation. The blower impeller is under high centrifugal loads in operation and these loads have caused damage to the corners of the blower impeller blades. The first attempt to solve this problem was to increase the thickness of the blades. The results achieved were better than the damaged blower design, but improvement is still needed to achieve the targeted design. Increasing the thickness of the blades resulted in heavier designs and other problems. In the second experiment carried out in the study, different materials were used. Aluminum 7075 T6 has almost the same density as aluminum 6082 T6 material, but has a higher yield stress. Therefore, aluminum 7075 T6 material has been the right choice to achieve the desired blower impeller design. A new design was produced according to the simulation results obtained, and the desired performance and life in the final design were obtained according to the observations and experiences.

The results obtained from the study show that analysis software is very important and necessary for designing complex machines. The solutions obtained as a result of the analysis studies now show that high speed and weight do not play a critical role in the failure of the blowers.

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Author Contributions

Lezgin KAYA: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing, Project administration
Betül GENÇASLAN: Methodology, Software, Investigation, Resources, Writing - Original Draft, Writing - Review & Editing, Visualization
Sezgin BALCİ: Conceptualization, Methodology, Validation, Investigation, Supervision, Project administration
All authors read and approved the final manuscript.

Conflict of interest

No conflict of interest was declared by the authors.

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