

Structural Analysis of Compressor Connecting Rod Using Finite Element Simulation in SolidWork

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Article Information	ABSTRACT
Article History Received : June 24, 2025 Revised : July 16, 2025 Published : July 26, 2025	The connecting rod in a compressor plays a critical role in transmitting the reciprocating motion from the piston to the crankshaft, making it a vital component that is constantly subjected to cyclic loads and stresses. This study aims to evaluate the structural strength and reliability of a compressor connecting rod by utilizing Finite Element Analysis (FEA) through SolidWorks Simulation software. The connecting rod was modeled with realistic geometric dimensions and material properties commonly used in household refrigerator compressors, such as aluminum alloys or medium-carbon steel. The simulation was performed by applying realistic boundary conditions, including compressive forces, reaction loads from the crankshaft, and constraints reflecting actual operational conditions. The results of the finite element simulation provided insights into the stress distribution, deformation patterns, and safety factors of the connecting rod under various load conditions. The maximum von Mises stress was identified in the transition area between the rod and the crank pin, which is consistent with typical failure points found in previous studies. From the analysis, it was concluded that the existing design provides an acceptable safety factor under normal working conditions, but optimizations in material thickness and fillet radius at critical regions could further enhance durability and reduce the risk of fatigue failure. This study highlights the importance of structural analysis in improving the reliability and longevity of compressor components through simulation-based design validation.
Keywords: <i>Connecting rod; Finite Element; Structural Simulation; Stress Distribution; Safety Factor.</i>	

INTRODUCTION

Refrigerator or cupboard cooler is tool house ladder powerful electricity that uses refrigeration or cooling process for preservation food (Mandouw et al., 2020) .System cooling and refrigeration very much important in a cooling food, refrigeration usually happen in the cooling process. The term refrigeration alone refers to the retrieval process hot from a room or objects and transfer them to environment surrounding areas, so that create difference desired temperature. Refrigeration very important in lots applications, including cooling room, storage food, cooling equipment industry, and transportation items that need temperature under control. This process utilise properties physics from substances certain, such as refrigerant gases, for

change phase from liquid to gas and vice versa, so absorb and release heat. Technology cooler is means for increase welfare man (Chen et al., 2025).

System the simplest refrigeration own component main that is compressor, condenser, valve expansion, and evaporator (Ardy et al., 2024). Components this work together in cycle certain for create flow desired heat. In addition that, refrigeration can also controlled use various methods and technologies, including thermostat electronics, systems automation, and temperature sensors. Development technology refrigeration keep going to be continued for increase efficiency energy, reduce use material chemistry dangerous, and reduce impact environment in a way overall (Muhammad et al., 2019). Component most important in compressor is connecting rod or often called axis crank on the piston. Connecting rod functioning for continue style from crankshaft to stem piston through crosshead to be able to withhold burden when compression, connecting rod must stand bent (Anwar, 2020). Reliability and strength connecting rod this very crucial for ensure efficient operation from system cooler. Selection material for connecting rod become factor determinant in reach objective mentioned. Besides from function mechanics, importance connecting rod is also visible in context performance machine. Connecting rod during the refrigeration process is also often worn and broken consequence too much burden height, lack lubricants and quality less connecting good.

A disadvantage of compressor pistons is excessive friction between the piston rod and the cylinder, resulting in reduced efficiency, increased temperature, and accelerated wear. Research by Ilman & Barizy (2015) shows that wear on components such as the piston rod directly impacts the long-term performance of the compressor by causing pressure leaks and reduced volumetric efficiency. This friction also demands optimal lubrication, and a failure in the lubrication system will accelerate piston rod failure (Ilman & Barizy, 2015); Chen et al., 2025b; Li et al., 2024). Furthermore, piston rods tend to generate excessive vibration during the compression process, resulting in higher operational noise levels than rotary or linear compressors. Research by Park et al. (2019) notes that vibrations caused by the piston mechanism are a major source of noise in household refrigeration units. These vibrations also risk causing misalignment, which can have long-term impacts on the wear of the piston rod itself. Furthermore, piston rod reliability is influenced by the materials and manufacturing methods used. Less wear-resistant materials or defects in the manufacturing process can reduce the piston rod's durability under very high cyclic loads. According to Riad et al. (2010), fatigue failure or failure due to repeated load cycles is a common cause of piston rod damage in small compressors such as refrigerators.

Connecting rod is between crank shaft and crosshead, working for continue movement (style) of crank shaft to piston rod via cross head (Pasau & Hetharia, 2022). Connecting rods have role and importance in the refrigeration process, as well as keep going push innovation in the material, we can ensure performance more machines good, more efficient, and more reliable in the future. Selection material medium alloy steel for connecting rod is not decision that is not right. Medium alloy steel, with controlled composition and diversity characteristic mechanically, it becomes choice main because capable overcome stress, displacement and safety factors that often occur found in cycle work compressor refrigerator. Study This choose medium alloy steel as material aluminum substitute, offering a number of benefit significant, including improvement power, performance thermal, stability dimensions, convenience fabrication, and potential savings cost (Hamada et al., 2023; Karthick et al., 2023). Research this only give description general about objective main choose medium alloy steel as material replacement aluminum. Specific details and analysis deep done for determine the most optimal material for every application. Usage medium alloy steels are like that rapid and diverse in the world of engineering in line with need industry steel for develop alloy suitable steel with needs, things this aiming for recognize characteristics steel alloy as well as prevent the occurrence failure of material (Leni , 2023).

The researcher aims to test Medium Alloy Steel material on the refrigerator compressor connecting rod application. This study will focus on the simulation of testing the refrigerator compressor connecting rod material made of Medium Alloy Steel. The study was conducted using the Finite Element method with the help of Solidworks software that can test the

connecting rod construction to determine the value of Stress Von Misses, Displacement and Safety Factor Performance, Medium Alloy Steel material.

RESEARCH METHODS

This study was conducted to analyze the performance of a refrigerator compressor connecting rod made of medium alloy steel through preparation, mesh determination, material testing, design evaluation, loading analysis, simulation, and analysis stages. The following are the steps of the research methodology carried out. Finite Element Method Simulation Finite Element Analysis (FEA) is used to predict the response of a structure to loading (Hamada et al., 2023; Karthick et al., 2023; Zhu et al., 2025). The simulation process begins by importing the 3D design that has been created into the simulation software, as well as inputting mechanical data into the software based on the tensile test results. The next process is meshing, also known as model discretization, which is carried out to ensure the accuracy of the results. Static and dynamic loads are applied according to the calculations carried out in the loading section, with fixed support conditions (Chen et al., 2024). The simulation results aim to analyze the von Mises stress, which shows the stress distribution in the structure. Furthermore, deformation analysis is used to evaluate the total deformation by measuring the change in shape due to loading. Finally, a safety factor analysis is carried out to ensure the use of medium alloy steel materials for safe refrigerator compressor connecting rod applications.

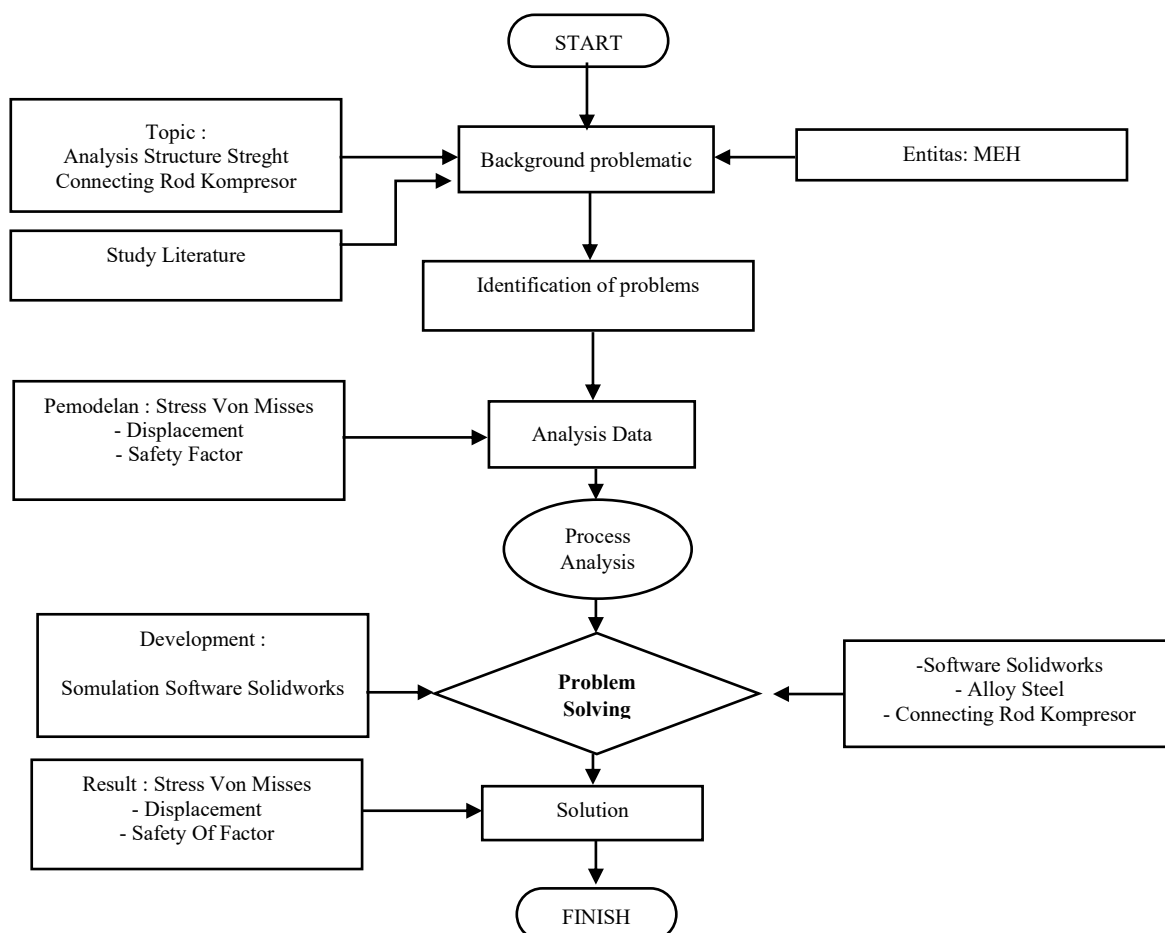


Figure 1. Flowchart Study

This study analyzes von misses stress, displacement and safety factor. refrigerator compressor connecting rod made of medium alloy steel using solidworks premium 2019 software. Solidworks software is a CAD (Computer Aided Design) program solidworks software

with ability modeling three solid dimensions for manufacturing process object 3D prototypes visually, simulation and drafting along with documentation the data (Purohita et al., 2021).

2D and 3D design

Designing 2D in Solidworks software and doing it measurement in a way directly on the connecting rod compressor refrigerator.

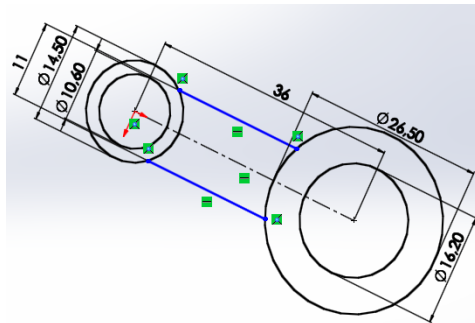


Figure 2. 2D Design

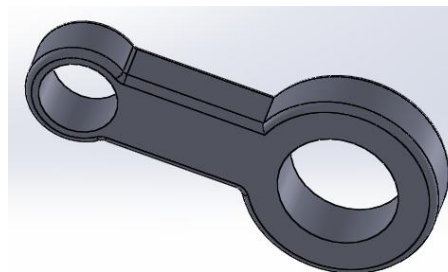


Figure 3. 3D Design

Input Material Properties

3D design is done, step furthermore is enter the material properties of medium alloy steel to design compressor connecting rod refrigerator. The steel used in structure is steel construction (alloy steels) or steel alloys that are generally contain more of 98% iron and usually not enough from 1% carbon (Melinda et al., 2021).

Load Input

Input burden on research this aiming for know strength connectinrod compressor 1/6 PK refrigerator with R134a freon with pressure 3,800N and 5,700N. Conditions burden experienced connecting rod moment experience loading because of the freon gas with normal pressure of 10 Psi during the refrigeration process. According to (Akmal et al., 2020) calculation in determine burden use formula as following:

$$F p \max \frac{\pi.D^2}{4} Pmax$$

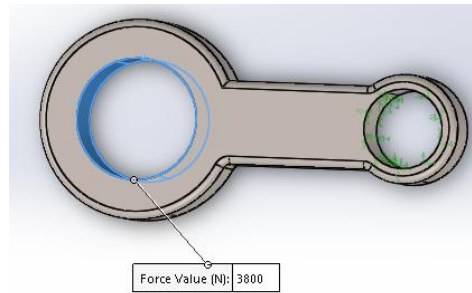


Figure 4. Connecting Rod Loading

Meshing

Meshing is the process of dividing a 3D geometric model into elements small called mesh

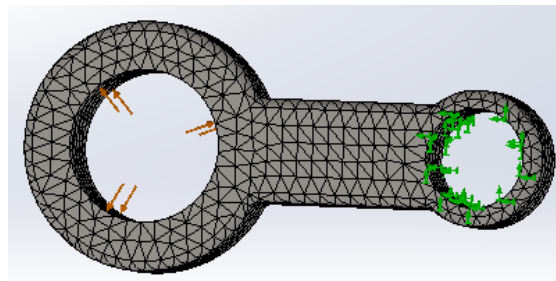


Figure 5. Connecting Rod Loading

RESULTS AND DISCUSSION

Stress Von Misses (Tension)

Von Mises stress value must compared to with yield strength of the material used. If mark mises stress exceed yield strength, then the material has the potential experience yielding or deformation plastic permanent. In matter this mark yield strength of medium alloy steel material 620422000 N/m^2 can it is said safe for used connecting rod compressor refrigerator.

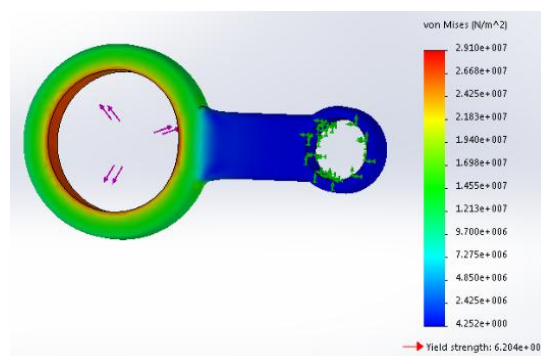


Figure 6. results simulation *stress from misses* load 3,800 N

Simulation results use software solidworks mark stress von misses on the compressor connecting rod refrigerator made from medium alloy steel with load 3800 N obtained minimum result on structure reach $4.252e+000 \text{ N/m}^2$ or equivalent with 0.000004252 Mpa and the value the maximum $2.910e+007 \text{ N/m}^2$ or equivalent with 29.1 MPa .

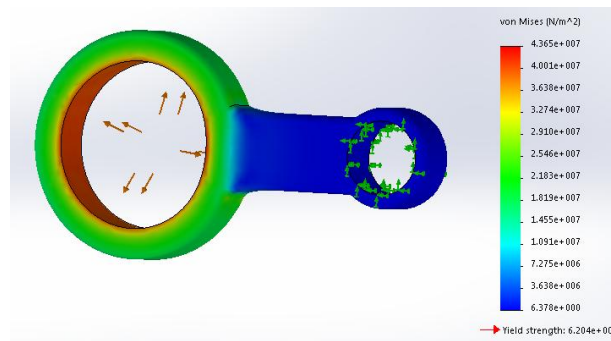


Figure 7. results simulation *stress from misses* load 5,700 N

The results of the second load simulation of 5,700 N obtained a minimum von misses stress of 0.000006378 Mpa and a maximum value of 43.65 Mpa.

Table 1. Von Misses Stress Simulation Results (Stress)

Testing	Style	Results (Min)	Result (Max)
<i>Von Mises Stress</i> (Tension)	3,800 N	4.252e+000	2.910e+007
<i>Von Mises Stress</i> (Tension)	5,700 N	6.378e+000	4.365e+007

The results are still stage safe see from curve voltage strain because under 600,000,000 N/m². The critical area with the highest stress occurs around the drive shaft hole. Simulations also reveal that the maximum stress is still below the yield strength of the material (29.1 MPa), indicating that the medium alloy steel material in the refrigerator compressor connecting rod application is safe from deformation under this load condition. The geometry around the drive shaft hole causes stress concentration due to the drive shaft and sudden geometry changes (Karthick et al., 2023; Zhu et al., 2025; Dirisu et al., 2019).

Displacement

Maximum value displacement in simulation connecting rod with a load of 3,800 N is 1,414 N/mm² and the value the minimum 0 N/mm². Simulation results safe from displacement Because elastic return to condition beginning and below voltage maximum on the curve voltage strain.

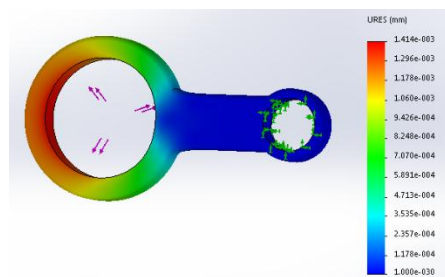


Figure 8. results simulation *Displacement* load 3,800 N

Results for loading 5,700 N Maximum value displacement t 2.121 N/mm² and the value the minimum 0 N/mm².

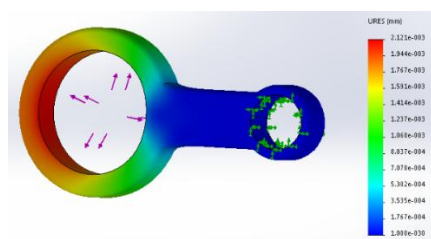


Figure 9. results simulation *Displacement* load 5,700 N

Maximum value displacement happen in the circle big connecting rod used as piston connector works. Displacement value must compared to with limit tolerance permissible deflection based on table characteristic mechanic medium alloy steel. If mark displacement exceed limit tolerance, then structure potential experience failure functional or no can fulfil condition desired performance. With matter this with 5,700 N connecting rod loading no experience large displacement so that safe for used.

Table 2. Simulation Results *Displacement* (Deformation)

Testing	Style	Results (Min)	Result (Max)
<i>Displacement</i>	3,800 N	0 N/mm ²	1.414 N/mm ²
<i>Displacement</i>	5,700 N	0 N/mm ²	2.121 N/mm ²

Analysis of total deformation on the refrigerator compressor connecting rod shows minimal deformation, which does not have a significant impact on the functionality of the refrigerator compressor connecting rod. Medium alloy steel, with a modulus of elasticity, shows sufficient stiffness while still being able to absorb energy from the load without experiencing significant deformation (Muhammad et al., 2019; Chen et al., 2025; Kumar et al., 2024).

Safety Factor

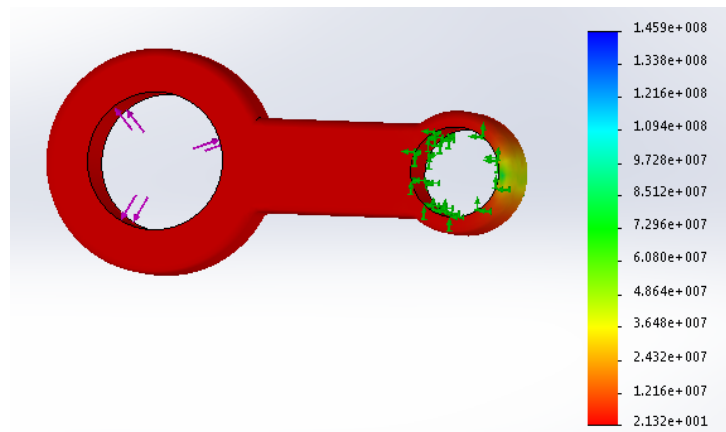


Figure 10. results simulation *Safety Factor* load 3,800 N

Safety Factor Formula

$$Fos = \frac{\text{Yield Strength}}{\text{Tegangan maksimal yang terjadi}}$$

$$Fos = \frac{620400000000 \text{ N/m}^2}{2910000000 \text{ N/m}^2}$$

$$Fos = 21.3195876289$$

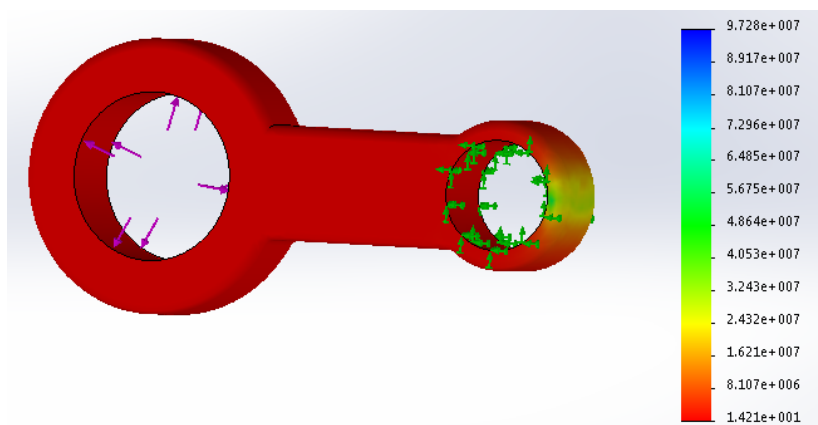


Figure 11. Results simulation *Safety Factor* load 5,700 N

$$\text{Safety Factor Formula} \quad Fos = \frac{\text{Yield Strength}}{\text{Tegangan maksimal yang terjadi}}$$

$$Fos = \frac{620400000000 \text{ N/m}^2}{43650000000 \text{ N/m}^2}$$

$$Fos = 14.2130584192$$

Factor security is factors that indicate level ability a material technique accept a burden from outside (Ibrahim et al., 2024). *Safety factors* is indicator important For evaluate level security structure to failure. *Safety factor value* counted with compare strength maximum that can be held. *Safety factor value* on connecting rod compressor *Medium Alloy Steel* material refrigerator is 21 and 14.

Table 3. Simulation Results Safety Factor

Testing	Style	Results (Min)	Result (Max)
<i>Safety Factor</i>	3,800 N	1.459e+008	2.132e+001
<i>Safety Factor</i>	5,700 N	5,700 N	9.728e+007

The results of the safety factor analysis vary, with a minimum value above 2.1. This value indicates that the medium alloy steel refrigerator compressor connecting rod has a high enough safety margin to withstand the applied load. The geometry of the medium alloy steel refrigerator compressor connecting rod effectively distributes the load, keeping the maximum stress low (Hamada et al., 2023 & Cao et al., 2025). The resulting stress remains well below this limit, resulting in a high safety factor (Hamada et al., 2023 & Cao et al., 2025). The maximum dynamic load of 5700 N has been conservatively estimated, ensuring that the safety factor remains high.

CONCLUSION

The simulation results show that the maximum stress (von Mises stress) occurs at the transition area between the connecting rod and the big-end hole (crankshaft). This area is the most critical point that has the potential for failure due to the accumulation of cyclic stress. The analysis stops completely, the value that occurs is still within reasonable tolerance limits and does not interfere with the main function of the connecting rod in the compressor system. The safety factor value obtained from the simulation shows that the existing wiring rod design is still safe enough to be used under normal operating conditions for household compressors. However, if the workload exceeds the design specifications, the potential for failure due to fatigue still needs to be considered. The results of this study provide input that design optimization such as increasing the fillet radius in the critical transition area, or improving materials with better fatigue resistance, can improve structural durability and extend the service life of the component.

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