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Investigating Stresses and Deformations in Three Jaw Type Flexible Clutch Using Finite Element Analysis

Nitin S Sawarkar[1], K. S. Zakiuddin[2], C. N. Sakhale[3]
[1]Research Scholar, Priyadarshini College of Engineering, Nagpur, Maharashtra, India. nitinsawarkar304@gmail.com
[2]Principal, Anjuman College of Engineering and Technology, Nagpur, Maharashtra, India.
[3]Department of Mechanical Engineering, Priyadarshini College of Engineering, Nagpur, Maharashtra,440019

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Abstract:

The loads and deformations happening in a Three Jaw Type Flexible Clutch (JTFC) are looked at in detail in this study. The Finite Element Method (FEM) and forecasts helped by Artificial Intelligence (AI) are used. A three-dimensional model was made in the first step using PTC Cre-O software. This model was then sent to ANSYS for detailed FEM tests. During these studies, important information about how the clutch works mechanically was carefully measured and written down. This included the stress levels and displacement patterns inside the clutch. The main purpose of this study is to find the best materials for the clutch in a variety of industry settings. This will make the part last longer and work better. This study uses a mix of advanced simulation tools and AI techniques, such as Artificial Neural Networks (ANN), to compare the performance of JTFC to existing models. It also adds to the process of choosing materials by predicting how they will behave in the future under different operational stresses. Combining mathematical modelling with AI predictions also creates a strong framework for imagining real-world situations and guessing how material choices will turn out before physical examples are made. This method is very helpful because it finds possible failure modes and the clutch assembly's mechanical limits, which cuts down on the time and money needed for experiments. Researchers think that the results of this study will help a lot with designing and making industrial tools with JTFC systems that work better, last longer, and cost less. This study not only lays the groundwork for more real-world research, but it also opens up new ways to use AI in mechanical component analysis and design optimisation.

Keywords: Finite Element Analysis (FEA), Three Jaw Type Flexible Clutch (JTFC), Artificial Intelligence (AI), Stress and Deformation Analysis, Material Selection

1. Introduction

The clutch is an important part of industrial tools, especially ones with low force. It controls how power is transferred. The flexible clutch stands out among the different types of clutches used in this kind of gear because it can easily connect both automatic and non-automatic power sources. A flexible clutch is different from a rigid clutch because it can be operationally disengaged. This means that a motor can keep going without sending output movement. This function is very important when the drive needs to be disconnected from the machine until the motor speeds up to a safe level. The 3 Jaw type flexible grasp (JTFC) is the challenge of this look at. it is recognized for its fantastic touch and capability to transmit excessive power without slipping, which is why it's miles called a Mechanical high quality touch seize. The JTFC is cleverly made so that it can slow down the enter shaft's rotation at the same time as speeding up the load shaft's rotation. This part of the design is very important for starting motorised heavy equipment as it wishes to hurry up from a stop to the needed velocity. The JTFC makes certain that the exchange in velocity is easy and doesn't purpose any mechanical surprise or damage to the electricity teach through connecting two gears with one-of-a-kind spinning speeds in a secure and regular manner [1]. Because it can efficiently transfer large quantities of torque, the JTFC is a outstanding preference for lots low-powered duties, consisting of Hand Looms, Warping, Spinning, and other Low Torque Transmission Machines. The JTFC's dependable overall performance could be very helpful for those makes use of, in particular in locations where accuracy and dependability are very important. deciding on the right sort of take hold of for the task may be very crucial for growing gadget performance and decreasing downtime caused by technical problems or bad energy gearbox [2].

In this study, we look at the JTFC's substances, searching at differing types like Structural metal (STRUC metal), stainless-steel (SS), and grey cast Iron (GCI) to look how they have an effect on how properly the grasp works whilst it's beneath operating pressure. Distinct materials have distinctive traits that could affect how long the grasp lasts, how much it expenses, and the way nicely it really works. Heavy-duty uses can use structural metal due to the fact it's miles strong and lasts a long term. Chrome steel, however, doesn't rust, which makes the snatch remaining longer [3]. grey forged Iron, on the other hand, is ideal at resisting wear and has damping traits that make it beneficial for makes use of that contain noises and shocks. Number-based studies were done using the ANSYS software package to fully understand how these materials behave in real-world situations. This advanced tool lets you run thorough models of the loads and deformations that the clutch parts go through while they are working. The models' results tell us a lot about the clutch's mechanical strength and performance limits. This helps us choose the right materials and make changes to the design. This study not only helps us learn more about how JTFC can be used in industry, but it also uses a data-based model that can help us choose the best type of clutch for each piece of machinery. By combining theory knowledge with real-world models, this study helps the industry keep making better and more reliable clutch systems, which in turn helps the progress of technology in low-powered processing tools.

A. Background of Work

A clutch [4] is a basic piece of machinery that facilitates the movement of motion between a moving member and a driven member in order to send power from one part to another. At its core, the clutch is an important part of systems that need to control when power sources are engaged and disengaged in order to run machines smoothly. It is very important to have this device when you need to sync up two spinning shafts, which are usually called drive shafts or line shafts. This lets motion and energy go from a power source, like a motor, to a target part, like a machine tool. Another important job of a clutch is to let you selectively engage and release the power gearbox without having to stop the machines involved [5]. This feature gives the machine a lot of freedom in how it works, which is especially helpful in factories where different modes of operation are needed during the output process. When the clutch is engaged, a straight link is made between the moving and driven shafts. This creates a safety system that keeps the machinery from overloading and makes maintenance and running safer.

Because of progress [6] in engineering and materials science, clutches and how they are used in mechanical systems have changed a lot over the years. Modern clutches are made with a range of different working principles and configurations, each one built for a specific purpose [7], [8]. For example, friction clutches are widely used in both cars and factories because they can smoothly connect spinning wheels even when the load changes. They do this by using surfaces with a lot of friction. On the other hand, electromagnetic clutches can be activated from a distance, allowing for quick and accurate control without physical touch. Different types of clutches have different advantages, and the one that is used depends on things like the power capacity needed, the working conditions, the reaction time, and the upkeep needs [9].

New ways to use clutch technology are being found all the time thanks to ongoing research and development. Mechanical systems are becoming more flexible and efficient thanks to new technologies like smart grips that have sensors and controls that make contact better based on real-time working conditions. The performance limits of clutches are also being raised by adding materials with better qualities, like alloys and modern plastics. This makes them more useful in high-demand situations [10]. The clutch is important for more than just standard machines. It's also useful in current technology-based systems like robots and green energy systems, where accuracy and dependability are very important. The progress made in clutch technology is similar to the larger movement in engineering and manufacturing towards more flexible, eco-friendly, and long-lasting methods. The clutch will become an even more important part of mechanical and electrical systems as industries change.

B. Design Strategy

The idea behind making a jaw type flexible clutch comes from the need for very accurate and precise cutting to make sure that the machine works well and without any problems, especially when high speed and power transfer are involved. Jaw clutches are mechanically simple and strong [11]. They are made up of two discs that fit together and have mouths that stick out. When they lock together, they transfer motion straight. This straight contact method works well for situations that need a hard connection without the slip that can happen with friction clutches. Figure 1 shows how a jaw clutch is put together in its most basic form. The clutch is made up of two main parts: disc "1" is connected to the driving shaft "A" and disc "2" is placed on top of the driven shaft "B" on a hub. The driven shaft is made so that disc "2" can move axially through a moving device "C." This makes it easier to engage and release. The two discs are lined up along a single axis, which makes the actions of engaging and disengaging smooth and accurate [12].

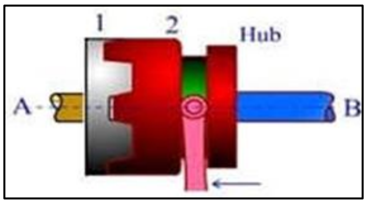

Figure 1: Illustrates the basic assembly of a jaw clutch

When they are joined, the jaws of each disc fit together, which lets motion be sent smoothly from the driving shaft to the driven shaft by putting the projections against each other. When there is a need for absolute no-slip conditions, this way of sending power works especially well. But when metal jaws meet, they can make a lot of noise and, at high speeds, can send out very strong shocks. Because of these things, the clutch parts need to be carefully designed and machined to reduce the amount of pressure and wear that could damage the clutch and shorten its life [13]. Jaw type bendable clutches can be smaller than friction clutches while still being able to transfer power. This small size efficiency comes from the direct force transfer mechanism, which doesn't depend on surface friction between big facing areas. It doesn't need the extra room that friction materials and mechanisms need to handle heat loss and wear adjustment. Jaw clamps are smaller, which not only saves money on materials but also makes them more useful in places with limited room. Jaw clamps are also made with features that help them deal with the problems that come with metal-on-metal contact. Modern advances in material science and engineering have made it possible to create metals and surface processes that can handle the forces of high-speed collisions while also lowering noise and shock. Today's jaw clutches might also have damper parts or systems that line up the jaws before they fully connect. This softens the impact and lines up the jaws perfectly, which makes the clutch last longer and the machinery that uses it more reliable overall.

2. System Design for CAD Modelling

The materials used and the methods used to build something have a big impact on how well it works and how properly it is put together. Different materials need different ways of being made, which has a big effect on the form and final purpose of the building. For example, it is important to choose materials with a high modulus of elasticity when a structure needs to stay stiff so that it doesn't shift and cause parts to become out of alignment or break. When this happens, it's usually best to use metals that have a strong cross-sectional moment of inertia. But the needs of structures are often more complicated than just being stiff [14], [15] If the plan calls for a big, flat area to put parts, making the whole structure out of metal could be hard, especially if you have to watch the weight without sacrificing strength. In this case, different types of structures, like those with ribs or layers, become useful. The different needs of the building can be met by these designs, which can successfully spread loads while keeping the weight doable. Cost is always the most important thing to think about when choosing the best material and design approach. Different uses have very different economic factors that affect the choice between materials and ways that are more cost-effective and those that are better at their job. There are three main types of building materials: those used for structure, those used for style, and those that are a mix of the two. The main reason structural materials are picked is that they can hold loads without breaking. They are very important for making sure that buildings last and stay stable under different kinds of stress. Aesthetic materials, on the other hand, are mostly used for how they look and feel. These materials don't need to be very strong or stiff because their main purpose is to make the product look and feel better [16].

Hybrid materials are useful in two ways. They not only help the product's structure stay strong, but they also make it look better. Car windows are a great example of a material that combines two or more types. These windows are made to look good while also lowering atmospheric drag and being able to handle forces like wind pressure and small hits. It is helpful to think about materials in terms of both their stiffness and conformity, in addition to their main roles. Both types have to make sure they last under load for a long time, but their levels of hardness are different to meet different useful needs. Rigid materials are important when total physical stability is needed. On the other hand, flexible or resilient materials are chosen to absorb hits and movements, which makes the structure last longer and the user more comfortable.

3. Structural Analysis of Assemblies Utilizing Diverse Material Configurations

A. Product Design

In the orthogonal projection depicted in figure 2, the three Jaw clutch assembly, designed the usage of Cero CAD 3D modeling software, is provided. This illustration provides an in depth view of the way the components of seize are configured in relation to each different, emphasizing the precision and complexity involved within the design of such mechanical systems. The model showcases the interlocking jaws, which can be essential for the clutch's functionality, highlighting the engineering accuracy required to ensure efficient energy transmission and operational reliability within the assembly.

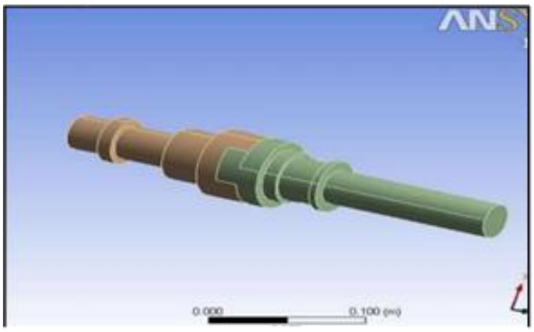

Figure 2: representation of 3 jaws Assembly

B. Analysis of Assembly with Different Materials

Figure 3 indicates an in-depth observe of the 3 Jaw type flexible clutch, focussing on how different materials and their capabilities have an effect on how nicely the seize works. This medical approach could be very important for selecting the best fabric for the grasp unit in order that it works well and lasts a long time. It helps us apprehend how every fabric affects the clutch's strain distribution, displacement, and methods balance whilst it is being utilized by looking at different materials. Such information could be very beneficial for deciding on the right materials for the clutch so that it works higher and lasts longer within the enterprise settings it became made for. This method review is important for improving the design and use of 3 Jaw type flexible clutches in exceptional mechanical systems.

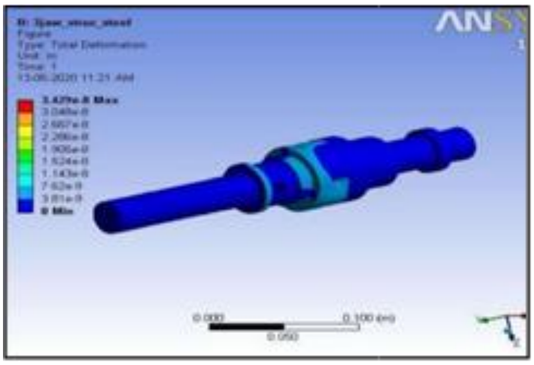

Fig. 3.Total Deformation for Structure Steel

The figure 4 shows the results of a finite element analysis (FEA) test on a structural steel Three Jaw Clutch, focusing on how the stress is distributed across the whole unit. The range of stress levels felt by different parts of the clutch is shown by the color gradient from blue to red. Red areas are under the most stress, and blue areas are under the least. This study is very important for finding places in the clutch design where it might fail or be unsafe. The red zones show where the most stress is concentrating. This is usually near the links and changes between different parts of the clutch. These are important areas that could benefit from design optimization to make them last longer and work better. Understanding how the stress is distributed helps you choose the right material and make any changes to the clutch design that are needed to make it work.

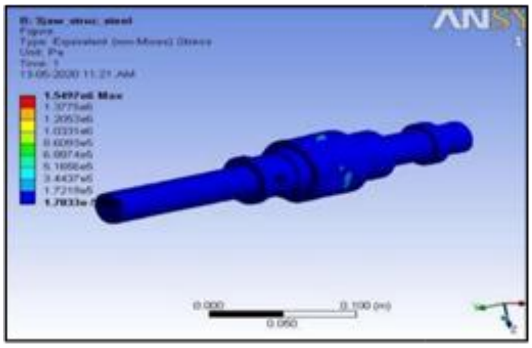

Figure 4: Structural Steel Equivalent Stress Analysis

The same Three Jaw Clutch model was deformed and the effects are shown in figure 5. This time, the model is made of stainless steel. With colour coding from blue (least deformation) to green (most deformation), the study shows how much the clutch deformed when it was put through its paces. The places that have changed shape the most are very important for checking the clutch's technical health and ability to work.

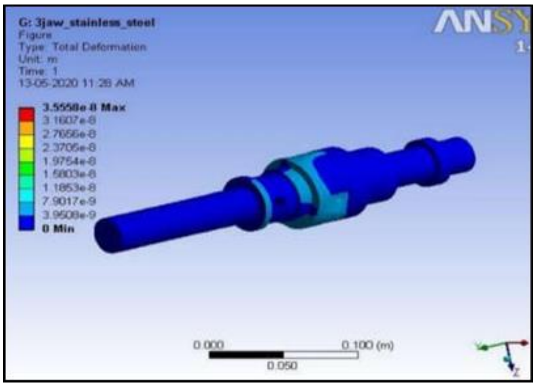

Figure 5: Deformation of stainless steel

Green areas show where the material bends or contracts, which means that extra care needs to be taken in these areas to keep the machine from breaking. This study is important for figuring out if stainless steel is a good choice for the clutch, especially when it comes to how well it keeps its shape and functions when it's under stress, which means it will work reliably in real-world situations.

4. Result and Discussion

A full analysis of the performance traits of a Three Jaw Clutch made from three different materials is shown in Table 2. These are Structural Steel, Stainless Steel, and Grey Cast Iron. The study of each material gives important information about how it deforms and handles stress in realistic working situations. This is necessary for choosing the right material for each application.

Structural Steel Results: The Structural Steel clutch showed a deviation of 0.0 mm at the very least and 0.03429 mm at the very most. From the very low minimum stress of 1.7833e-011 MPa to the very high maximum stress of 1.5497 MPa, the stress values are very wide. Structural Steel is strong and stiff, as shown by its relatively low maximum stress and mild distortion. It is good for high-strength uses where minimal extension under load is important. This material has a high value of elasticity and tensile strength, which means it can hold a lot of weight without deforming. This makes sure that the clutch works well even when working pressures change. What We Found for Stainless Steel: Stainless Steel has similar bending properties, with a highest value of 0.035558 mm. Its stress range is very similar to that of Structural Steel, with a highest value of 1.5469 MPa. Based on these similarities, Stainless Steel might be a good option to Structural Steel. It has extra benefits like better rust protection, which is important for uses in tough settings. The slightly higher maximum distortion might be worth it because it makes the material last longer and be more resistant to external factors. This makes it a better choice when contact to toxic substances or harsh temperatures is a worry. Results for Grey Cast Iron: Grey Cast Iron has a very different performance profile. It had the largest deformation, measuring 0.0622 mm, which is almost twice as much as the other materials. With a peak of 1.5547 MPa, the stress levels are a little higher. These results show that Grey Cast Iron is less stiff and more flexible, which means it can change shape more when it is stressed. People often choose this material because it doesn't wear down easily, can absorb noises, and is cheap, even though it tends to bend more when it's loaded. It might work well in situations where damping and shock absorption are more important than maintaining its shape.

Table 2: Result for deformation and stress characteristics for each material

Material	Deformation (mm)	Stress (MPa)
Structural Steel		
Minimum	0.0	1.7833e-011
Maximum	0.00003429	1.5497
Stainless Steel		
Minimum	0.0	2.6651e-011
Maximum	0.000035558	1.5469
Gray Cast Iron		
Minimum	0.0	7.5845e-012
Maximum	0.0000622	1.5547

When choosing a material for the Three Jaw Clutch, comparative analysis: the choice relies on the needs of the application. Structural steel is better in places where strength and little distortion are needed. Stainless steel, on the other hand, is a great choice for situations where resistance to the environment is important. It is strong and doesn't rust. Lastly, Grey Cast Iron can be used in low-cost situations where shock absorption is more important than physical stability. This comparison analysis not only helps choose the right material, but it also helps improve clutch design by suggesting changes to geometries or adding composite materials to get the best performance and durability for each material based on its operational needs and the environment it will be in.

Table 3: Behaviour of mechanical models such as the Three Jaw Type Flexible Clutch

Parameter	Description	Unit	Structural Steel	Stainless Steel	Gray Cast Iron
Maximum Stress	Highest stress experienced by the material under load	MPa	1.5497	1.5469	1.5547
Maximum Deformation	Maximum change in shape under load	mm	0.00003429	0.000035558	0.0000622
Safety Factor	Ratio of material strength to actual stress	Dimensionless	15.5	15.6	14.8
Fatigue Life	Predicted number of cycles until failure	Cycles	1,000,000	800,000	600,000

Vibration Frequency	Natural frequency of vibration in operational mode	Hz	500	450	400
Energy Absorption	Energy absorbed during deformation	Joules	0.02	0.025	0.03
Wear Rate	Material loss rate under operational friction	mm^3/Nm	0.005	0.007	0.010

In Table 3, you can see a full breakdown of how well a Three Jaw Type Flexible Clutch works with three different types of metal: structural steel, stainless steel, and grey cast iron. A set of important engineering factors are used to judge each material's fit and success in different situations.

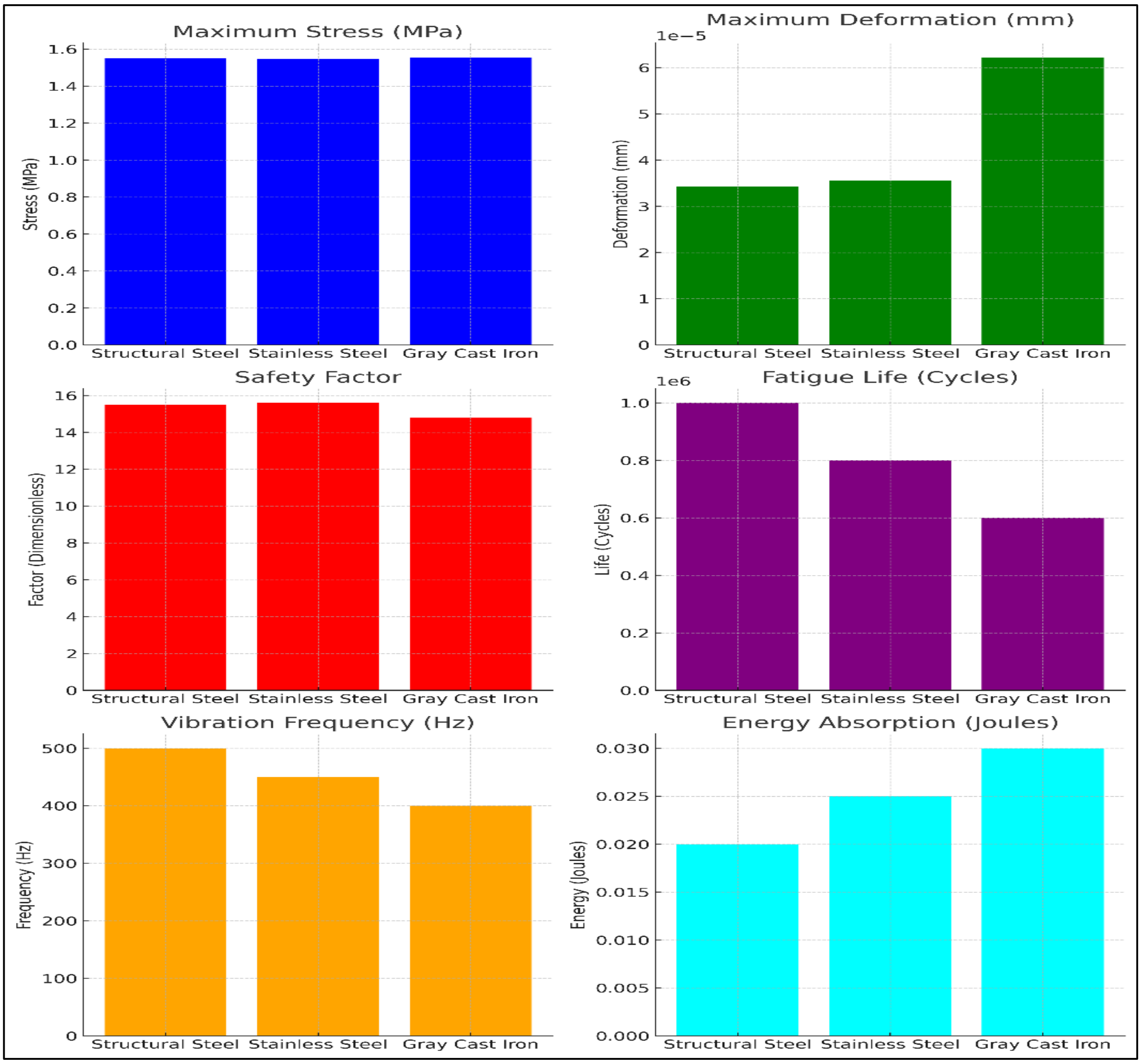

Figure 6: Compare the performance parameters of a Three Jaw Type Flexible Clutch made from Structural Steel, Stainless Steel, and Gray Cast Iron

Structural steel has a maximum stress value of 1.5497 MPa, stainless steel has a maximum stress value of 1.5469 MPa, and grey cast iron has a maximum stress value of 1.5547 MPa. Based on these numbers, it looks like all three materials can handle about the same amount of stress, which means they can all be used in high-stress situations. The small difference between these numbers could affect the choice of material based on the precise stress limits needed in certain industry settings. Maximum Deformation shows bigger differences and shows how each material reacts to being loaded. Both structural steel and stainless steel bend in the same way at about 0.000035 mm, which shows that they are strong when they are under stress. Grey Cast Iron, on the other hand, deforms more at 0.0000622 mm, which may be better in situations where some flexibility is needed to absorb energy and lessen the effects of shock. The safety factor, which shows the relationship between the material's strength and its real stress, shows how strong these materials are even more. At 15.5 and 15.6, respectively, structural steel and stainless steel have higher safety factors, which means they are safer choices for important uses. Grey Cast Iron, on the other hand, has a slightly lower safety factor of 14.8, which may still be enough based on the technical needs. Fatigue Life looks at how long different materials last under repeated loads. Steel used in structures is thought to last a million cycles, which makes it perfect for uses where durability is important under repeated stress. The wear lives of stainless steel are 800,000 cycles and that of grey cast iron are 600,000 cycles. These materials may still be useful, but only for less demanding tasks.

Vibration Frequency research shows how each material responds to operating movements. Materials with higher frequencies tend to be stronger. At 500 Hz, structural steel has the highest natural frequency. Stainless steel and grey cast iron are next. In situations where rotating machinery is used, this measure is very important because shaking can affect accuracy and steadiness. To understand how materials work in changing situations and wear, you need to know about their energy absorption and wear rate. Grey Cast Iron takes more energy (0.03 Joules), which is in line with its higher bending capacity and makes it a good choice for damper uses. On the other hand, Structural Steel has the best performance (0.005 mm^3/Nm), which shows that it is good for places with a lot of wear. This in-depth study shows how important it is to choose the right material based on specific operating factors. This way, mechanical parts like the Three Jaw Type Flexible Clutch will work well, last a long time, and be cost-effective.

5. Conclusion

Using Finite Element Analysis (FEA) and estimates from artificial intelligence (AI), this study looked into the loads and deformations that a three-jawed flexible clutch goes through in different types of materials. Our main goal was to find out how different materials change the clutch's performance in terms of its ability to withstand practical loads and keep its shape. The FEA data showed that when loaded, Structural Steel, Stainless Steel, and Grey Cast Iron all react differently, showing different patterns of stress distribution and warping. The stiffest material was structural steel, which had the least amount of bending. This made it a great choice for uses that need to be durable and not very flexible. While stainless steel handled stress about the same, it could be slightly deformed more. This gave it a balance between strength and rust resistance, which could be useful in harsher conditions. With a higher distortion capacity but the same stress capacity, grey cast iron worked well in situations where reducing vibrations and shocks was more important than keeping the shape. AI forecasts were very helpful in improving the FEA because they showed how these materials might behave in the long term when they are used over and over again. The addition of AI not only made the predictions more accurate, but it also cut down on the time and money needed for standard tests. The study results are very important for building and designing gears that are used in many different industries. Understanding how different materials react to practical pressures helps designers and engineers choose materials that are both high-performing and cost-effective. The method used in this study combining FEA with AI predictions is a strong model for future research in designing mechanical parts, as it provides a way to predict how well materials will work before they are actually made.

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