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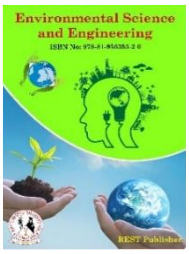

Design and Analysis of the Braking System to Improve Heat Dissipation by Utilizing the Multi-Material Concept

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Abstract: *A drum brake consists of a rotating cylinder that is pressed against by a set of shoes or pads, which creates friction. Cast iron is the typical material for this. When the brakes are applied, friction develops on the drum's inner surface, slowing or stopping the wheel's rotation and bringing the vehicle to a halt. The development of heat, especially in the braking systems of automobiles, is the primary issue that must be dealt with. Brake drums for cars are typically constructed of cast iron. Multi-material brake drums, such as those with a Nickel alloy coating over cast iron, have replaced traditional brake drums. The behavior of these two setups needs to be investigated. Brake drum modeling is being done in CREO, and ANSYS will be used for structural and thermal analysis. Stress, strain, and heat dissipation % are just few of the factors we'll be comparing. Additionally, we have conducted nickel coating experiments on cast iron using an electroplating procedure, varying the layer thickness from 10 to 15 to 25 microns.*
Keywords: *ANSYS, CREO, Brake drum.*

1. INTRODUCTION

A drum brake is a type of mechanical braking system in which brake shoes or pads apply outward pressure against a revolving cylinder-shaped component known as the brake drum, creating friction. In most contexts, when people talk about a "drum brake," they mean a type of brake in which shoes contact the drum's inside. A clasp brake is one in which shoes press against the outside of the drum to stop the vehicle. A pinch drum brake is a type of brake in which the drum is compressed between two shoes in a manner analogous to that of a standard disc brake. A band brake, of a similar design, employs a flexible belt or "band" wrapped around an outer drum.

FIGURE 1. Drum Brake

Drum Brake in Operation: Now things start to get a little trickier. Self-activating brakes are common in drum models. As seen in Figure 5, when the brake shoes make contact with the drum, they undergo a sort of wedging movement that causes them to be pressed more firmly into the drum. Drum brakes are more efficient than disc brakes since they employ a smaller piston because to the wedging motion. However, when the brakes are removed, the shoes must be withdrawn from the drum via a wedging movement. Some of the springs exist for this very purpose. Other springs assist in keeping the brake shoes in position and returning the adjuster arm once it has been moved.

Advantages: To list advantages of drum brakes:

- The benefits of drum brakes include:
- cheaper to manufacture..
- Due to superior corrosion resistance, disks require less frequent upkeep..
- Less external energy (such hydraulic pressure) is needed to activate the system's built-in self-energizing action.
- Comparatively speaking, wheel cylinders are easier to recondition than calipers.

Slight weight reduction due to the use of hydraulic cylinders, which are substantially more compact and lightweight than calipers.

Disadvantages: Overheating also causes brakes to fade. This could be the result of a single process, or more likely, the result of a number of processes working together. Drums expand somewhat in diameter when subjected to high temperatures, requiring the driver to apply more force to the brake pedal in order to achieve the same stopping distance.

Electroplating Process: Whether it's to protect one metal from corrosion or to add a shiny finish, electroplating is a common technique. With the help of an electric current, dissolved metal cations are reduced, resulting in a thin, coherent layer of metal on the electrode. Silver chloride electrodes are made by electroplating silver wire with silver chloride, an electrical oxidation of anions on a solid substrate.

Electrode Components In electroplating, the anode is the positive electrode and the cathode is the negative electrode; the current comes from an external source. Electrochemical reduction reactions take place at the cathode. The anode is the site of the oxidation reaction in an electric current.

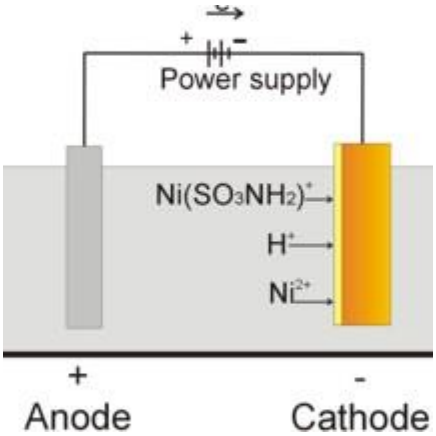


FIGURE 2. Electro plating Work

2. LITERATURE REVIEW

The During squeal, both the drum and the shoes hold complex modes, which can be best visualized as the superposition of pairs of similar normal modes phase shifted both spatially and temporally relative to one another, as Allan Michael Lang [1] found in his investigation. Mohd Zald Bin Akop [2] concludes in his project that the development of modern vehicles has placed a premium on safety, and that all vehicles must be equipped with an effective braking system. Based on his research, Ramesha. D.K et al. [3] found that a truck's aluminum-alloy brake drum can withstand higher temperatures than its cast-iron counterpart. It was also determined that brake drums made of aluminum alloy suffered less heat distortion than those made of cast iron. His research suggests that aluminum is preferable to cast iron for making brake drums because of its lighter weight. According to NurulhudaBinti Khalid's [4] research, brake drum temperature variations during deceleration provide heat distribution, and heat distribution depends on elements including friction, surface roughness, speed, and others. The braking efficiency of trucks can be increased by evenly applying pressure to each wheel, as was concluded in a report by Ray W. Murphy et al [5]. According to the findings of Mr. SongwutPutti Srinivas Rao et al. [6], adding a fin to the exterior of a drum brake improves its ability to dissipate heat. The yearly fin made of highly conductive material is ideal for a drum brake with a rectangular cross section, allowing for optimal heat transmission at the expense of added weight. As a result, the triangular fin is optimal for maximizing heat transfer while simultaneously minimizing mass. Professor Vidyadhar R. Bajaj and colleagues [7] offered two variations on the standard brake drum design. All patterns are crafted from a unique FG260, SS: 4404 gray cast iron. To improve heat transfer, as in the first proposed design, material is removed from the drum's outer surface. When compared to the standard drum, this new design cuts weight by 4.74 percent. By decreasing the wall thickness from 13 mm to 7 mm in proposed design-2, the section is optimized. The drum of the second design is

4.06% lighter than the original drum. Using computational fluid dynamics (CFD) research, we show that this approach successfully reduces drum weight. Drum brakes are often employed to stop or slow down moving bodies, reducing velocity and acceleration, as concluded by Anup Kumar et al. [8] in their structural and thermal analysis of drum brake research. It has been noticed that the transient temperature rises with each cycle. This demonstrates that the drum will not cool in the allotted time.

3. MATERIALS AND METHODS

Brake drums are typically built of cast iron, though aluminum has been utilized in some vehicles, especially for front-wheel applications. Aluminum has better heat conduction than cast iron, thus it dissipates heat more efficiently and causes less fading. Unsprang weight can also be reduced by using aluminum drums instead of iron ones.

Gray Cast-iron: The low melting point of cast iron is what makes it so valuable. Cast iron is any of several iron-carbon alloys having a carbon concentration of more than 2%. There are three types of cast iron, each of which breaks differently depending on the alloy's composition: white cast iron, which contains carbide impurities and allows cracks to pass straight through; grey cast iron, which contains graphite flakes that deflect a passing crack and initiate countless new cracks as the material breaks; and ductile cast iron, which contains spherical graphite "nodules" that stop the crack from further progressing.

TABLE 1. Material properties of gray cast-iron

Properties	Gray Cast-iron
Tensile Strength (MPa)	250
Young Modulus (GPa)	105
Fatigue Resistance (MPa)	110
Heat Conductivity (W/mK)	48
Hardness(HB)	179 –202
Relative Damping Capacity	1.0

Nickel alloy: Nickel alloys are ideal for high-performance applications like jet-engine blades due to their resistance to high pressures and temperatures. They are not easily corroded either. Because of the corrosion risk posed by seawater, Monel is employed in deep-sea mining. Nickel and nickel alloys are non-ferrous metals that are renowned for their strong higher temperature capabilities, corrosion resistance, and overall strength and toughness. Niobium in its purest form is a silvery white metal that is both tough and pliable. Pure nickel is sturdy and resistant to corrosion, making it a great material from which to forge unique alloys.

TABLE 2. Material properties of Nickel alloy

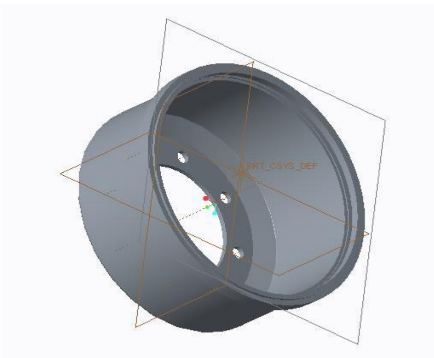
Properties	NickelAlloy
Tensile Strength (MPa)	482.62
Shear Modulus(MPa)	1.0
Elastic Modulus (MPa)	179.26
Mass Density (g/cm3)	8.829
Yield Strength (MPa)	193.05
Thermal Conductivity (W/mK)	3.584
Specific Heat(J/g0C)	0.460087
Poisson Ratio	0.31

4. MODELING AND ANALYSIS

Even when it comes to mechanical engineering, design, manufacturing, and CAD drafting service companies, PTC CREO (formerly known as Pro/ENGINEER) is the 3D modeling software of choice. It was revolutionary since it was one of the first parametric systems to be utilized in 3D CAD modeling software. Optimizing both the product's development and its design are possible thanks to its use of parameters, dimensions, and features to capture the product's behavior. In 2010, the program was rebranded as CREO from its previous moniker, Pro/ENGINEER Wildfire. Parametric Technology business (PTC), the business responsible for its creation, unveiled it alongside the debut of a suite of design products. The suite includes tools for assembly modeling, 2D orthographic views for technical drawing, finite element analysis, and more. Finite element analysis is a technique used to approximatively resolve various engineering and scientific challenges. It is typically employed for issues that lack a precise mathematical formulation. Therefore, it is a quantified rather than analyzed. The genuine, complex problems encountered in engineering are beyond the capabilities of analytical methods, hence alternative approaches are required. For instance, the stresses and strains in a bent beam can be calculated analytically using engineering strength of materials or the mathematical theory of elasticity, but these approaches will not be very helpful in determining what happens in a segment of a car's suspension system when cornering. For linear, nonlinear, and dynamic structural analysis, ANSYS Mechanical is a useful finite element analysis tool. The wide variety of mechanical design issues can be tackled with the help of this computer simulation product's finite elements for modeling behavior, as well as its support for material models and equation solvers. In addition to acoustic, piezoelectric, thermal-structural, and thermo-electric analysis, ANSYS Mechanical is also capable of thermal analysis.

TABLE 3. Parameters of Brake drum design

S. no	Parameter	Value	Unit
1	Dust Shield Recess diameter	480	mm
2	Brake Face Diameter	460	mm
3	Brake Face Width	180	mm
4	Overall Height	210	mm
5	Squealer Band Thickness	10	mm
6	Depth of Dust Shield Recess	10	mm
7	Hub Pilot	280	mm
8	Bolt Hole Diameter	20	mm
9	Number of Bolt Hole	6	
10	Bolt Circle Diameter	280	mm
11	Weight of Brake Drum	79	N



. **FIGURE 3.** 3D model of brake drum

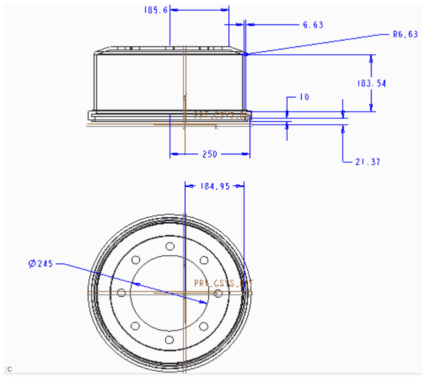


FIGURE 4. 2D design of brake drum

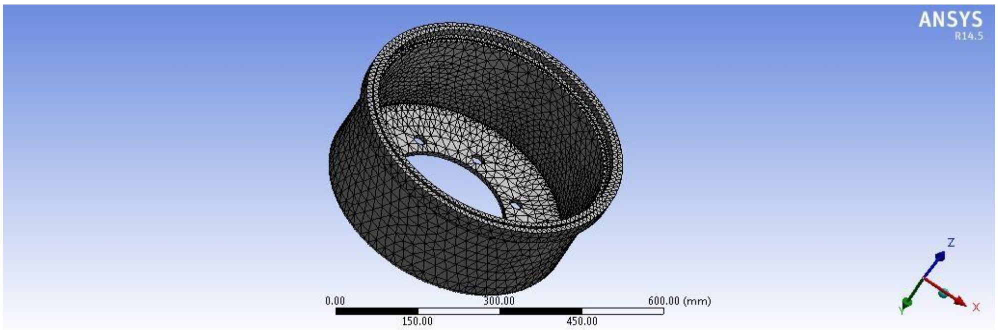


FIGURE 5. Linear Layer Analysis of Brake Drum

Table 4. layer stacking

Layer	Material	Thickness (mm)	Angle (°)
(+Z)			
7	NICKEL	0.023	90
6	NICKEL	0.023	0
5	NICKEL	0.023	0
4	Gray Cast Iron	10	0
3	NICKEL	0.023	0
2	NICKEL	0.023	0
1	NICKEL	0.023	-90
(-Z)			

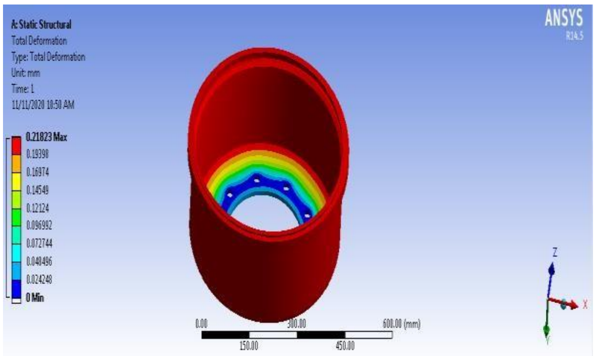


FIGURE 6. Total deformation

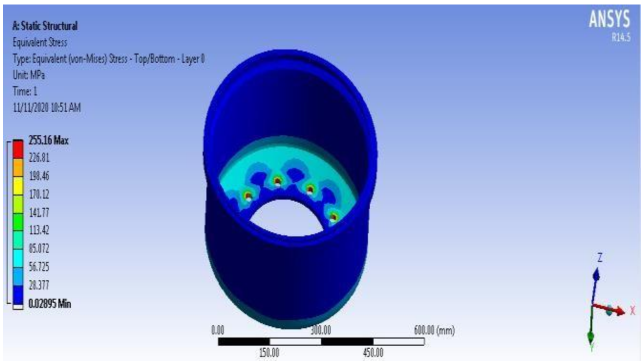


FIGURE 7. equivalent stress

The overall deformation of nickel-coated cast iron is shown in Figure 5 above. Brake drums are colored red at the point of greatest deformation, outside the drum, and blue at the point of greatest compression, inside the brake drum. Figure 6 depicts the equivalent stress distribution, with the highest value in the fixing area and the lowest value outside the brake drum.

Thermal analysis brake drum:

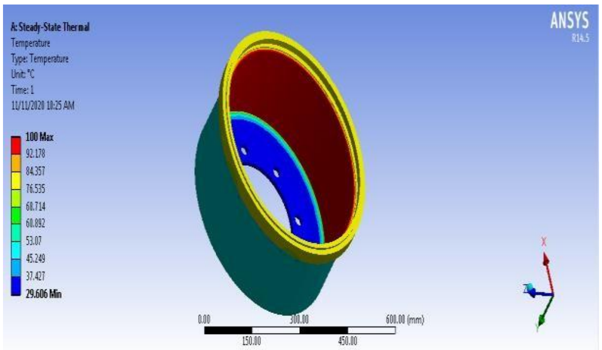


FIGURE 8. Temperature distribution

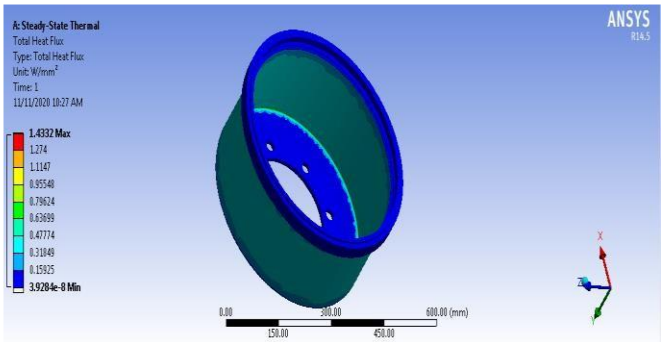


FIGURE 9. Heat flux

As can be seen in Figure 6, nickel alloys exhibit a rather even temperature distribution throughout their composition. Brake drums are colored red at the points where internal temperatures are highest and blue at the points where external temperatures are lowest. Maximum heat flow is displayed in Figure 8 on the interior of the brake drum, while minimum heat flux is displayed on the exterior of the brake drum.

5. EXPERIMENTAL SETUP

Electro Nickel Plating Process: Nickel electroplating, nickel electro-deposition, and other variations on the name are all gaining ground as common production processes. Electro nickel plating is a method of applying a thin layer of nickel to a conductive surface, often metal. Electroplating can also be done with metals like copper, zinc, and even platinum.

1. Cast-iron+Nickel10 µm
2. Castiron+Nickel15 µm
3. Castiron+Nickel25 µm

To improve a material's durability and corrosion resistance, an alloy treatment called electro less nickel plating can be applied. When compared to electroplating, the electro less nickel plating technique is more straightforward. Plating can begin without running an electric current through the chemical bath solution. Electro-Coatings, on the other hand, has mastered a sequence of cleansing and auto-catalytic reactions that are applied to the metal surface.

FIGURE 10. Nickel Electro plating process

It is possible to deposit anything from 5 microns per hour to 25 microns per hour of electro less nickel plating. The coating's thickness is theoretically unbounded because the process is ongoing and iterative. However, flaws of a microscopic nature become more noticeable with increasing thickness.

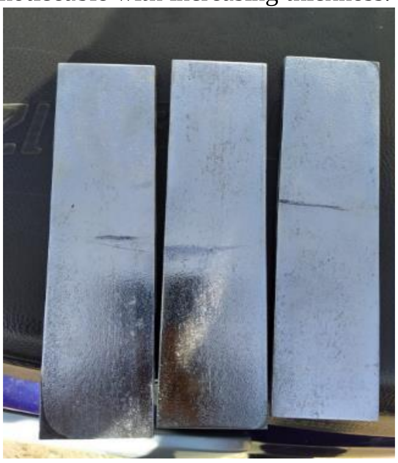


FIGURE 11. Final specimens

Tests Conducted: All the mechanical testing methods that were carried out were based on American Society for Testing and Materials (ASTM). There were four tests performed. They are;

- Tensile Test
- Hardness
- Flexural Test
- SEM

6. RESULTS AND DISCUSSIONS

Tensile Testing: This testing is also known as tensile testing. This is the fundamental material testing for all the materials in the engineering field, in which the sample is subjected to a controlled tension until failure. The purpose of this testing is:

1. Selection of a material for an application.
2. Predicthowa material will perform in use: normal and external forces.
3. To demonstrate the utility of a proposed material.

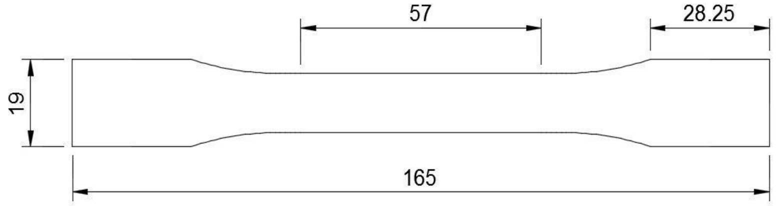


FIGURE 12. Tensile test specimen sketch

TABLE 5. Results of Tensile Strength of NICKEL coated plates

S. No	Samples	UTS(N/mm^2)	Elongation (%)
1	Castiron+Nickel10 µm	712.560	1.84
2	Castiron+ Nickel15 µm	806.219	3.46
3	Castiron+ Nickel25 µm	861.092	3.82

Hardness Results: A Rockwell hardness tester machine used for the hardness measurement. The surface being tested generally requires a metallographic finish and it was done with the help of 100, 220, 400, 600 and 1000 grit size emery paper. Load used on Rock well’s hardness tester was 200 gram sat dwell time 20 seconds for each sample.

TABLE 6. Results of hardness of NICKEL coated plates

Sno	Samples	HRC
1	Castiron+Nickel10 µm	23.67
2	Castiron+ Nickel15 µm	20.67
3	Castiron+Nickel 25µm	21.67

Flexural Test: Instrument for measuring hardness, based on the Rockwell scale. Emery paper in 100, 220, 400, 600, and 1000 grit was used to provide the metallographic finish necessary for the testing surface. Each sample was tested with a load of 200 grams and a dwell time of 20 seconds using a Rockwell hardness tester.

TABLE 7. Results of bending of NICKEL coated plates

Sno	Samples	Bending Strength
1	Castiron+Nickel10 µm	113.201
2	Castiron+ Nickel15 µm	112.437
3	Castiron+ Nickel25 µm	125.481

SEM Analysis:

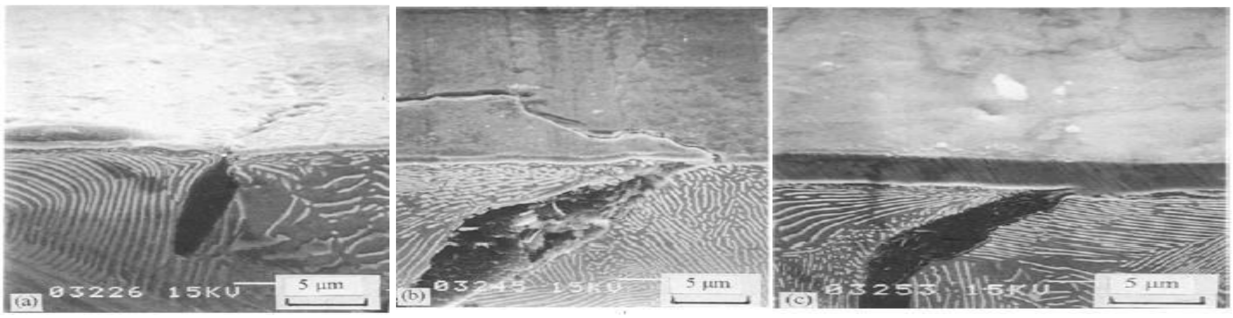


FIGURE 13. Surface changes after different treatment: (a) 10µm,(b)15 µm(c)25µm

1. Nickel at the plating film/substrate interface caused cracks, which were then spread into the plating film by bending tests.
2. AE observation can detect the onset of cracking and the breakdown of a film.

The plating film's strength was impacted by the concentration of nickel close to its interface with the substrate, and this strength reduced as nickel concentration increased.

7. CONCLUSIONS

Research into the use of materials is conducted to enhance braking efficiency and give higher vehicle stability. Static structural analysis is performed by coupling the thermal solution to the structural analysis, and the findings showed that the temperature field and the stress field during the braking phase were entirely connected. The study yielded results that are all below the minimum and maximum levels. Therefore, the brake drum layout is secure in terms of strength and rigidity. After examining the various analytical outcomes, it was determined that Nickel coated on cast iron was the optimal material choice. Additionally, we have tested electroplating nickel onto cast iron at three distinct layer thicknesses: 10 microns, 15 microns, and 25 microns. The experimental results showed that a layer thickness of 23 microns produced the highest tensile and bending strengths when compared to other layer thicknesses.

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