

## Comparative Analysis of AISI 10B21 app Licable for Fasteners

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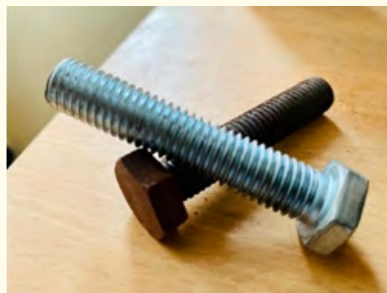
### Abstract

Manufacturing components and parts for a specific application are generally fabricated by traditional methods followed by industrial standards. With the modern era of machining components new materials, composites and alloys have also been developed for particular applications having desirable and required properties. Boron steel is one such material being used in manufacturing industries for agricultural spades, knives, blades, etc. in its raw form. In the present work, boron steel's properties and chemical composition have been compared when it is heat treated. It was observed that the working life span has been increased effectively and efficiently. This has also been verified using ANSYS.

**Keywords:** boron steel; heat treatment; ANSYS

### Introduction

Boron steels are expanding their applications, and they are becoming the first choice of industrialists for manufacturing products that need to be wear and corrosion free. Modern production techniques enable them to have high properties at a fair price [9-10]. Although boron steels were originally intended for hard, wear-resistant elements, they are now being promoted for a wider range of uses [5]. Boron's impact on improving harden ability makes it a useful alloying element with steel. It is added to carbon (C) and low alloyed steels at concentrations ranging from 0.0015% to 0.0030% to improve harden ability and improve the hardness level with strength. Because of how quickly it reacts with oxygen (O) and nitrogen (N), boron is not helpful for steels in their mixed form (N). As a result, Boron needs to be properly safeguarded while the steel is being made. The outcome of the heat treatment could be unexpected if this precaution is not taken [1].



**Figure 1:** Fasteners made of boron steel.

High strength low alloy (HSLA) structural steels and wear-resistant materials are two major advantages of Boron steels. These are offered as quenched and tempered steels or hot rolled steels. Boron assures that heavier plate parts can solidify sufficiently [11].

Type of Steel	Chemical Composition (%)									
Boro Steel	C 0.029	Mn 1.189	Si 41.25	Cr 0.183	S 0.238	P 0.002	B 0.002	Mo 0.150	Pb 0.3200	Ni 0.2500
AISI 10B21	0.18-0.23	0.80-1.10	0.30 (max)	0.10-0.20	0.03	0.03	0.0005-0.003	0.06(max)	0.0020 (max)	0.2000(max)

**Table 1:** Chemical composition of boron steel grades.

Applications include punching tools, spades, knives, saw blades, safety beams in cars, etc. Compared to alloy steels of comparable harden ability, C-Mn-B steels are economical and easily available. These manufactured grades of steel find application in crankshafts, drive sprockets, axle parts, track links, rollers, and earth scraper segments, among other things.

Of all the alloying elements, boron has the greatest effectiveness and capability to moderate [6]. Several low-carbon-boron alloy sheets of steel grades have recently been revealed and used. These alloys can reach high strengths, have great ductility at such strengths, are simple to produce, and are priced similarly to many other widely used fastener materials. The automotive industry's goal for improved characteristics increased dependability, and economic cost drives advancement in mechanical fasteners. These factors have caused automotive fastener users and manufacturers to have a great sense of material awareness. There are occasionally new materials introduced or existing materials modified that should be seriously considered as fastening materials [3].

An examination of the ensuing fastener characteristics:

1. **Hardness:** The resistance of a material to abrasion and indentation is measured by its hardness. Hardness is often described as a material's resistance to a test body's penetration under a specific load. Brinell and Rockwell hardness on carbon steels has been used to determine the fastener's tensile strength.
2. **Fatigue strength:** Even when the loads are well below the material strength, a fastener exposed to repeated cycle loads may abruptly and unexpectedly fail. The maximum stress that a fastener can bear for a predetermined number of cycles before failing is known as fatigue strength.
3. **Ductility:** It refers to a material's capacity for deformation before fracture. The ratio of a fastener's specified minimum yield strength to minimum tensile strength is a reliable indicator of its ductility. The fastener will be more ductile the lower this ratio is.

## Literature Survey

Boron steels are being used more often, particularly in industrial applications that demand strong wear resistance. Tools for digging, plowing, or plowing that operate under difficult conditions, are one application for this kind of steel. Hardness, abrasion resistance, and impact toughness are three highly sought qualities for materials used in agricultural machining that come into contact with the soil [1]. Bozkurt., et al. (2021) investigated three different heat treatment techniques and examined the tribological and mechanical characteristics of 30MnB5 boron steel used in agricultural mechanization. The as-supplied, quenched, and quenched cryo-treated-tempered samples' impact strength, hardness, and abrasive wear resistance are assessed. According to observations, quenching is a crucial heat treatment for using boron steel in agricultural settings. Tempering lessens the specimen's hardness, while cryogenic treatment combined with tempering improves impact toughness [1]. Rostislav., et al. (2019) conducted experiments on high boron steel that was used in agriculture, specifically for agricultural instruments like chisels, rings, and other items, and that featured two separate high boron cast iron chemical compositions with and without chromium content. The samples were in their cast state when they were put through a dry rubber wheel test to determine their wear-resistant qualities. It was determined that heat treatment and forging yield the optimum wear-resistant characteristics [2].

Mehta., et al. (2018) has studied the durability of boron steel (medium carbon steel, 22Mn5) used in agricultural equipment. A protective layer, or coating, was used to carry out the process. Good density and high wear resistance were among the fundamental characteristics of the coating that was offered. Pin-on-disc test rig was used to conduct wear tests after fabricating specimens. Analysis of the worn-out surface using SEM/EDAX and XRD revealed that powder with a high proportion of cerium oxide produces the best results, i.e., virtually zero wear loss when lubrication is carried out with a low value of applied load [3].

Falaleev, et al.. (2016). examined the modification of the mechanical characteristics of 22MnB5 steel under the effect of magnetic pulses and induction heating during restoration. The acquired results were validated by measuring hardness and comparing it to the evolution of the characteristics during hot stamping processes [4].

Frydman., et al. (2012) researched on boron steel using steel grade B27 as an example. Steel was evaluated following typical heat treatments because it is given in a state following hot rolling and the buyer is free to choose an appropriate heat treatment. Steel was examined in its delivered state as well as after normalizing, quenching, and quenching and tempering at various temperatures. The fundamental characteristics of strength, impact test and brittle fracture propensity, abrasion resistance, and corrosion resistance were examined. The investigations demonstrate significant variations in the measured parameters based on the heat treatment used, which should direct users to particular uses of this type of steel [5, 13].

Garcia SL., et al. (2015). Depicted the mechanical properties of stamped boron steel components that underwent ordinary subcritical annealing, quenching, and tempering to produce dual structural steel. Consequently, energy is conserved during the annealing process to lower the product's temperature and residence time and suppress the tempering process. Process economics as a result determines the end product's price and environment-related effects. This procedure aims to match the boron steel used in high-performance screws in the automotive industry with dual structural steel used for their high manganese and low carbon content. With the same strength and toughness characteristics as traditional treatments, this boron steel is used in these applications and subjected to quenching before subcritical annealing [6].

Choudhary, et al. (2017). Using concentrated electron beams to gather data, a scanning electron microscope (SEM) is a potent instrument for magnification. SEMs are extremely useful in a wide range of research and industry because the high-resolution, three-dimensional pictures they create give topographical, morphological, and compositional information. A scanning electron microscope can produce comprehensive surface information for solid items. It gathers input electrons and concentrates them onto a specimen; the electrons that scatter off the surface as a result of this interaction may then be examined using a variety of detectors to provide information about the surface of a sample's topography, morphology, and composition. Despite being bulky, expensive pieces of equipment, SEMs continue to be a favourite among researchers because of their many uses and capabilities, including the high-resolution, three-dimensional, detailed pictures they provide [12].

## Objective and Methodology

The main objective of this project is to find a solution for fasteners and nuts getting corroded and worn out. These are generally made up of boron steel AISI 10B21 as a major element. Fasteners made up are continuously being used and need to be reviewed, maintained, and repaired else change would be essential. Regular change of parts would not be so economical and time-consuming. This affects the strength and service life of the component. Hence, some hardening technique or heat treatment is necessary to enhance the working life. In this project work, we have tried the hardening process and the results have proved beneficial which is economic also.

Steel made of boron is an alloy of iron, carbon, and other elements. It has a favorable impact on the creation of the steel microstructure in modest doses, strengthening the metal. A fastener, often known as a fastening, is a hardware component that mechanically connects or fastens two or more things. Fasteners are typically used to construct non-permanent couplings or joints that may be taken apart without harming the parts they are connecting.

There are three main types of threaded fasteners:

1. Bolts.
2. Screws.
3. Studs.

1. **Rockwell Hardness Test:** As seen in fig. 2 the Rockwell hardness test is based on the measurement of the depth to which an indenter is forced by a heavy (major) load beyond the depth resulting from a previously applied preliminary(minor) load.
2. **Annealing Process:** As revealed in fig. 3 it is a heat treatment process that alters the microstructure of a material to change its mechanical or electrical properties. Typically, annealing is used in steels to reduce hardness, increase ductility and help eliminate internal stresses.
3. **Quenching Process:** Quenching involves the rapid cooling of a metal to adjust the mechanical properties of its original state. To perform the quenching process, a metal is heated to a temperature greater than that of normal conditions, typically somewhere above its recrystallization temperature but below its melting temperature as seen in fig. 4.
4. **Carbonitriding Process:** Fig.5 shows the heat-treatment procedure that enters the surface layer of steel components with carbon and nitrogen (through ammonia gas).
5. **Spectro Chemical Testing:** A physical method for analyzing a substance's spectrum to determine the atomic and molecular composition of the substance in both qualitative and quantitative as described in fig. 6.
6. **Normalization Process:** Normalizing is a heat treatment process that is used to make metal, such as steel, more ductile and tough.



**Figure 2:** Rockwell hardness.



**Figure 3:** Annealing process.



**Figure 4:** Quenching process.



**Figure 5:** Carbonitriding.



**Figure 6:** Spectrometer.

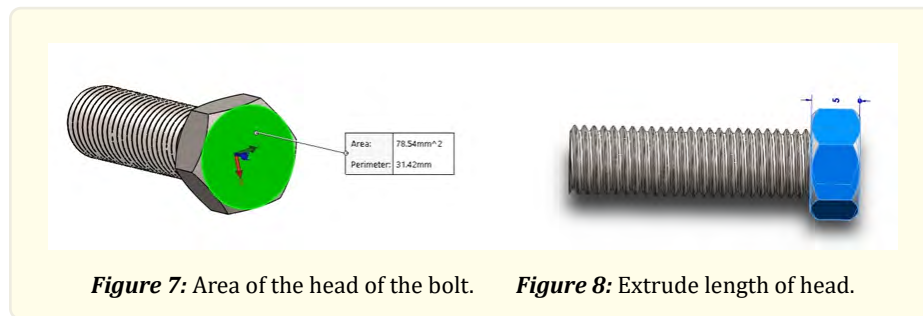
## Experimental Procedure

### DS Solidworks

Use Solid Works to create a 3D model of the bolt in the following steps:

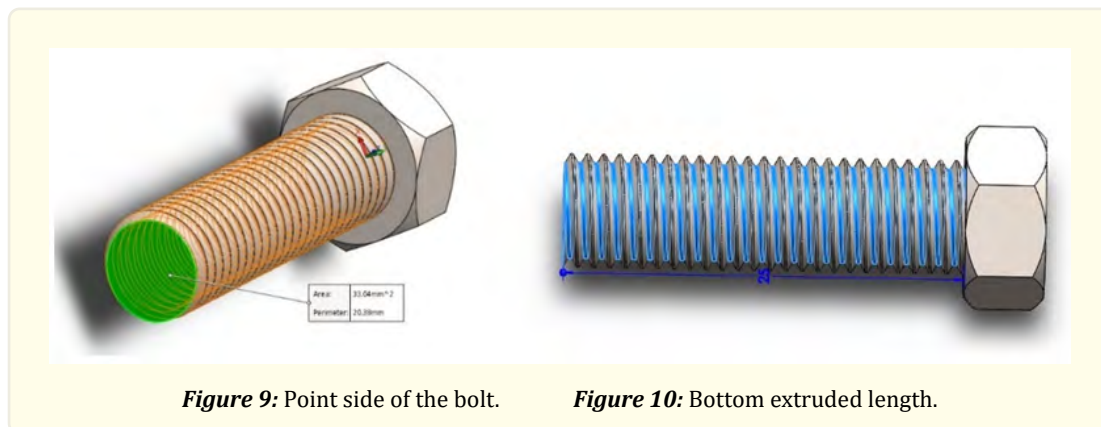
After selecting a file directory to save the model, we select a plane name X-axis where we drew the model, using the commands, and dimensions are mentioned accordingly below with steps and figures.

*Step 1.* We select the circle design command to draw the head part of the bolt with an area of  $78.54 \text{ mm}^2$  and a perimeter of  $31.42 \text{ mm}$ . (in fig.7).



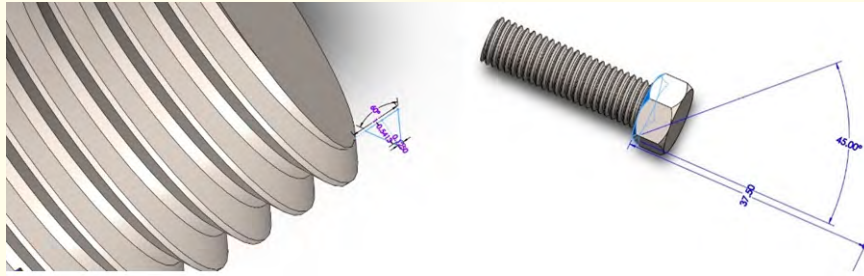
*Step 2.* After that, we used to extrude commands with a length of  $5 \text{ mm}$ . (in fig. 8).

*Step 3.* Now we select the bearing surface part of the model (mentioned above) as a plane where we select the circle command to draw the point side of the bolt, with an area of  $33.04 \text{ mm}^2$  and a perimeter of  $20.38 \text{ mm}$ . (in fig. 9).



*Step 4.* After this, we extrude the point surface to  $25 \text{ mm}$  to draw the bolt's grip length and the thread length. (in fig. 10).

*Step 5.* Now we used the helix command to give the thread in the length from the pointed surface to the bearing surface, with the helix angle of  $60$  degrees. (in fig. 11).

**Figure 11:** Helix angle.**Figure 12:** Revolve angle.

*Step 6.* Lastly, we use the revolve command to revolve the edges of the bolt, mentioned parts, where we used this command are the head, bearing surface, and point. The angle used in revolving the edges is 45 degrees.

### ANSYS

After designing the model in Solid Works, we also performed various analysis tests on Ansys like equivalent (von-mises) stress, equivalent elastic strain, and total deformation. Considering the material of the bolt is Boron Steel AISI 10B21 [8]. Initially, we import the Solid Works file extension of the bolt model (.stl) to Ansys file extension format (.iges) and then we save the file in the file directory of Ansys from where we import the file after a long press scrolling on the analysis system of static structural for generation of the file.

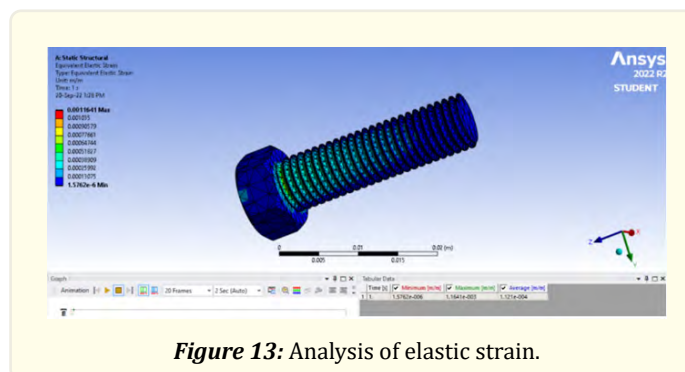
In static structural, we took these as a plane for 1 part, 1 body

- XY plane.
- ZX plane.
- YZ plane.

In below fig. 13, fig.14, fig. 15, we analyze equivalent elastic strain by transferring the same file in a static structural model, and then we got solution B6, right click on this and insert the option of equivalent elastic strain, total deformation, equivalent(von-mises) stress, taken plane XY and YZ. In, the below figures there is a chart of the maximum outcome moving accordingly towards the minimum outcome, the red box shows the maximum and the blue box shows the minimum.

*Step 1.* In equivalent elastic strain, we found this as result in unit 'm/m' with the time taken 1 sec. (in fig. 13).

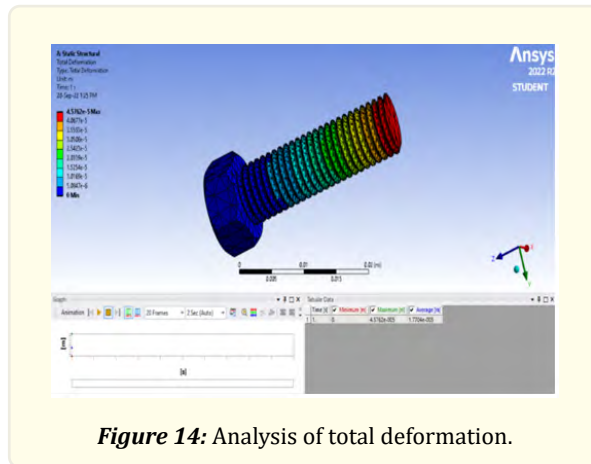
- Maximum - 1.1641e-003.
- Minimum - 1.5762e-006.
- Average - 1.121e-004.

**Figure 13:** Analysis of elastic strain.



Step 2. In total deformation analysis, we found this as result in the unit 'm' with the time taken as 1 sec. (in fig. 14).

- Maximum -  $4.5762 \times 10^{-5}$ .
- Minimum - 0.
- Average -  $1.7704 \times 10^{-5}$ .



Step 3. In equivalent (von-mises) stress, we found this as a result in unit Pascal (Pa) with the time taken as 1 sec. (in fig. 15).

- Maximum -  $2.3238 \times 10^{-8}$ .
- Minimum -  $1.2251 \times 10^{-5}$ .
- Average -  $1.878 \times 10^{-7}$ .

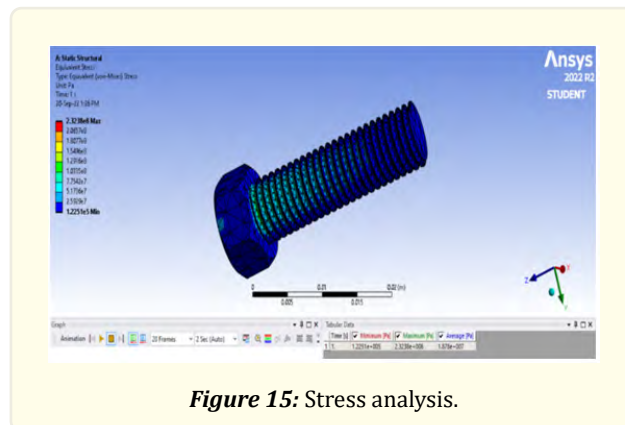


Fig. 16 shows that the bell furnaces are used to carry out heat-treatment procedures such as annealing, carbonitriding, quenching, and normalization.



**Figure 16:** Components of Bell Furnace.

Type of Steel	Chemical Composition (%)									
	C 0.250	Mn 1.350	Si 0.400	Cr 0.250	S 0.010	P 0.023	B 0.004	Mo 0.0400	Pb 0.0030	Ni 0.023
AISI 10B21	0.203	0.869	0.187	0.113	<0.00020	0.0118	0.0025	0.0200	<0.0020	0.0169

**Table 2:** Chemical composition of boron steel after the heat treatment process.



**Figure 17:** After the effect of AISI 10B21.

The above testing was also proved using ANSYS software. ANSYS is a general-purpose finite-element simulation software for numerically resolving a wide range of mechanical problems. These problems include electromagnetic problems as well as static/dynamic, structural analysis, heat transfer, and fluid problems.

## Summary and Conclusions

In the present paper we have analysed boron steel being used for fasteners in manufacturing industries with and without heat treatment. Results and composition have been verified by using software's like Solid works and ANSYS. In analysis, we perform testing like the Rockwell hardness test, Spectro chemical testing, and several heat treatment processes like the annealing process, quenching process, carbonitriding process, and normalization process. After these testing and processes, we found the changes in chemical composition in both materials' normal boron steel, as well as AISI 10B21 and the composition, are for normal boron steel (C-0.250, Mn-1.350, Si-0.400, Cr-0.250, S-0.010, P-0.023, B-0.004, Mo-0.0400, Pb-0.0030) and AISI 10B21 (C-0.203, Mn-0.869, Si-0.187, Cr-0.250, S-<0.00020, P-0.0118, B-0.0025, Mo-0.0200, Pb-<0.0020, Ni-0.0169).

To develop a remedy for tattered and tarnished fasteners and nuts. These are usually designed mostly of boron steel, AISI 10B21. Although fasteners are meant to be used repeatedly, they must be examined, maintained, and repaired to avoid the need for replace-



ment. The regular part replacement may not be as cost and time-effective [14]. The component's durability and strength are impacted by this. The working life must thus be improved by the use of a hardening method or heat treatment. In this project effort, we tested the hardening method, and the consequences have proven to be beneficial and economical as well.

Benefits of AISI 10B21 Boron steel, engineers can consider extending the technical requirements of present specifications while preventing any misuse of the steel. Fasteners should adhere to their intended operational setting [7]. Fasteners made of normal boron steel and hardened boron steel have a major difference in service life and ductility.

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