QUALITY IMPROVEMENT OF LOCALLY MANUFACTURED ALLEN KEY BOLT AND NUT

A PROJECT THESIS

BY

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Submitted to the department of Industrial and Production Engineering, Bangladesh University of Engineering and Technology, Dhaka, in partial fulfillment of the requirement for the degree of MASTER OF ENGINEERING in Industrial and Production.

Department of Industrial and Production Engineering

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THIS IS TO CERTIFY THAT THIS WORK HAS BEEN DONE BY ME AND IT HAS NOT BEEN SUBMITTED ELSEWHERE FOR THE AWARD OF ANY OR DIPLOMA OR FOR ANY PUBLICATION.

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To

My

Parents

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ABSTRACT

Industrial sector of Bangladesh has to depend entirely on some imported spare parts, but it requires long lead time for there procurement. This leads to huge inventory cost and lot of spares are kept in reserve in the fear of factory shut downs. Allen key Bolts and Nuts are critical spare parts in ceramic industry which has high usage value. The quality of allen key bolts and nuts found in the local market are of very poor. As an attempt to solve this problem the present work was performed. Under this work a comperative study of the local and imported spares parts were conducted. Chemical analysis, Vickers hardness, Proof Stress, Microstructure of the materials of these parts were studied. Apart from that the different parameters of thread of local and imported samples are analysed. From the analysis main causes of failure of the local samples are identified, suitable materials are selected and manufacturing process are developed for their manufacturing. Some Allen key Bolts and Nuts are manufactured on experimental basis. Different combination of heat treatment such as pack carburizing at different period of time and quenching are performed on both locally available and manufactured samples. The proof stress of these samples are checked for quality standard. It was observed that proof stress is increased with the increase of carburizing period for manufactured samples but in the case of local samples proof stress is decreased with the increase of carburizing period. For manufactured samples the proof stress was found within acceptable limit. Economic analysis was performed to evaluate viability of manufacturing the spare locally and it was found that local manufacture of spare parts with the target properties is economically viable and the country save a lot of foreign exchange.

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NOMENCLATURE

C	=	Carburizing.
Cr	=	Cromium.
Mo	=	Molybdenum.
T_1	=	absolute temperature.
t	=	time in hour.
Q	=	Quenching.
H.T.	=	Heat treatment.
σi	=	initial stress.
σp	=	Proof stress.
σy	=	Yield stress.
Fi	=	initial load.
VHN	=	Vickers Hardness.
μm	=	Micrometer.
hr	=	Hour.
D	=	Diameter of bolt.
T	=	Torque.
As	=	Stress area.
Ksi	=	Kilopound per square inch.
Mpa	=	Mega pascale.

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CHAPTER-1
INTRODUCTION

1.1 General

In Bangladesh most of the spare parts essential for the machineries in various industries are being imported from abroad. Recently a tendency has been observed to produce spares by using locally available material and technology. However, most of such attempts have not turned out to be such fruitful due to the lack of development of the required properties in the materials used for the manufacture.

1.2 Background of the study

Mirpur Ceramic Works Ltd. requires allen key bolt and nut as spare parts which can take high load. But this spare which are found in the local market have very low load carrying capacity. At the same time there is a ban on the import of this spare parts. Consequently the factory faces a practical problem which affect directly on their factory production. Keeping this problem in mind, investigation has been carried out to locally manufacture a allen key bolt and nut which can take high load as requirement.

Manufacturing of this spare parts is an engineering job. So, care should be taken in its manufacturing process. During this process factors like material selection, heat treatment of bolt and nut should be taken under consideration. Lack of adequate technological background on each of them may lead to reserve consequences. Therefore in order to get good quality product one has to consider all of them simultaneously at the preliminary stage.

Production process of this spare adopted by different Engineering workshop are based on mere experience. In our country an operator as well as an engineer pay less attention to this matter. At times there is a lack of their proper technical knowledge. Conseqently, the products of these workshop turnout to be of very low quality.

Apart from the above mentioned, it has been well recognised that successful transfer of technical knowledge is essential in order to utilize the modern technology properly. Otherwise the local engineering products will not be comparable to the foreign products. Thus the present study has been made with a view to enriching the technical knowledge in the field of allen key bolt and nut manufacturing in the country.The sketch of the specimen taken for investigation is shown in the Fig.1

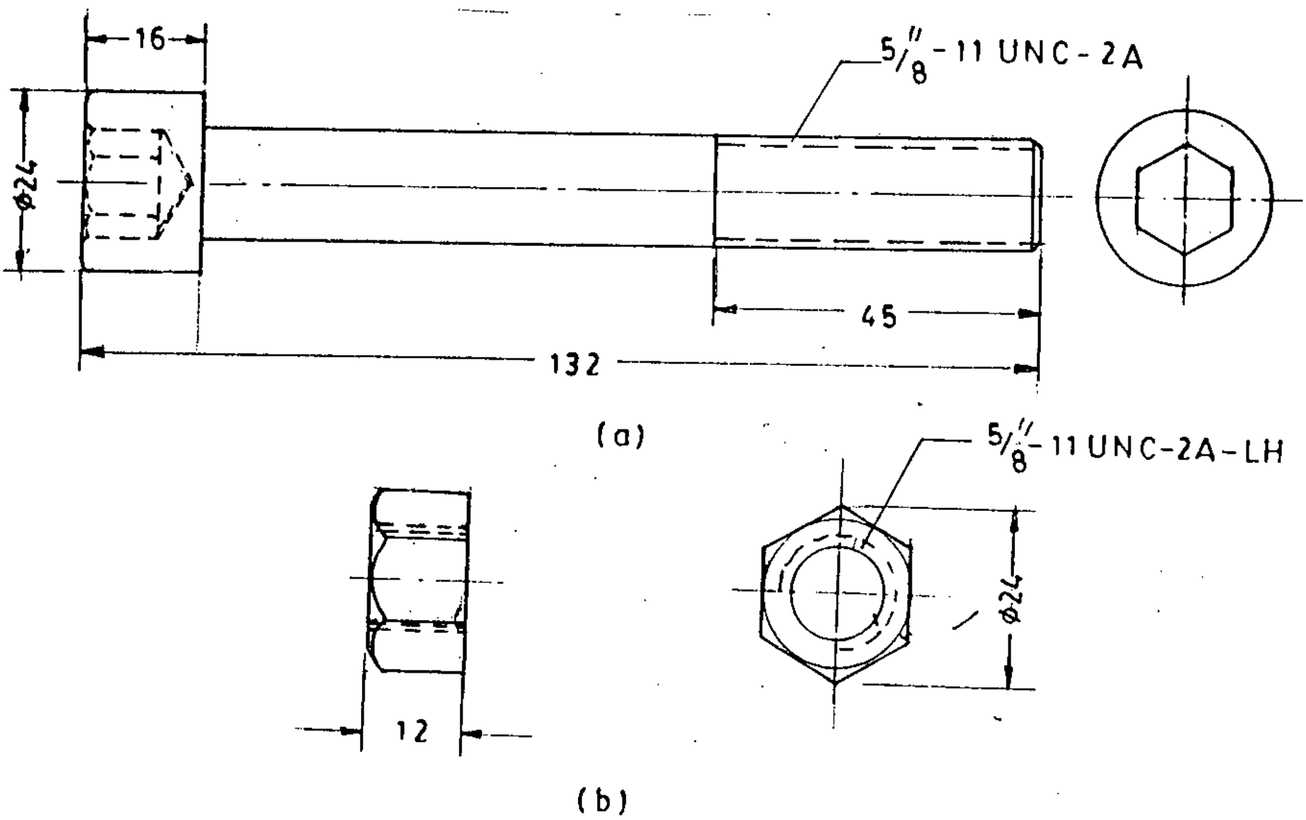


Fig. 1 Sectional view of a) Allen Key Bolt and b) Nut.

1.3 Aims and objectives

The aim of the project work is to conduct a comparative study of the properties, performance and load carrying capacity of locally manufactured and imported allen key bolt and nuts with a view to improving the quality of locally manufactured allen key bolts and nuts.

To achieve this aim following objectives are set on the present work.

i) To determine the chemical composition, Vickers hardness, Proof stress of both imported and locally manufactured allen key bolts and nuts.

ii) To study the microstructure of different allenkey bolts and nuts at different cross section to determine the phase combination and type of heat treatment of the spare parts.

iii) To study the manufacturing accuracy of threads of the imported and locally manufactured spares to identify the probable manufacturing defects of the locally made spares and the causes of these defects.

iv) To manufacture few samples of spares on experimental basis and improve the mechanical properties of the thread by an appropriate heat treatment technique and test their performance and load carrying capacity as against the imported samples.

1.4 Organization of the project work

This project is organized as follows:

Chapter-1 presents introduction on the project, chapter-2 gives a literature review, chapter-3 describes different aspects of thread, chapter-4 presents the experimental procedure, chapter-5 contains the result and discussion and chapter-6 contains conclusion and recommendation for future research work.

CHAPTER-2
LITERATURE REVIEW

2.1 SELECTION OF MATERIALS [20]

In designing spare parts the selection of material and the manufacturing process by which the parts are to be made should be considered together. The most economical design is arrived at by considering the total cost of labour, materials and overhead for each of a number of proposed designs that are satisfactory from a technical standpoint.

2.1.1 FACTORS AFFECTING THE SELECTION OF MATERIALS :

Economic factors, physical and mechanical properties that are involved in materials and process has a larger effect on the selection of material. Availability and cost of materials vary continuously, and as the change in towards favorable or unfavorable condition, design will necessarily undergo corresponding alterations for economic reason. At times certain materials may become unavailable for general industrial use and the necessity may arise for substitute design based on procured materials.

There are another various factors which may be considered according to application area and environment of the spares.

2.1.2 SAE NUMBERING SYSTEM :

The number for materials are given in the Table 2-1. The steel specifications represents the result of the cooperative effort of the American iron and steel Institute (AISI) and the society of Automotive Engineers (SAE) in a simplification program aimed at greater efficiency in meeting the steel needs of Industry.

The first digit of the four or five-numeral designation indicates the type to which the steel belongs. Thus 1 indicates a carbon steel, 2 a nickel steel, 3 a nickel-chromium steel etc. In the case of simple alloy steel, the second digit indicates the approximate percentage of the

Table 2.1 [20] SAE Numbering System

Material	Number	Material	Number
Carbon steels	1XXX	Ni-Mo (3.50% Ni)	48XX
Plain carbon	10XX	Chromium	5XXX
Free machining	11XX	Low Cr (0.5% Cr)	50XX
Manganese (intermediate)	13XX	Med Cr(1.0% Cr)	51XX
Nickel	2XXX	Chromium-vanadium	6XXX
3.5% Ni	23X	Cr 1%	61XX
5.0% Ni	25XX	Triple-alloy steels	0.55%
Nickel chromium	3XXX	Ni, 0.50% Cr. 0.25% Mo	86XX
1.25% Ni, 0.75% Cr	31XX	0.55% Ni, 0.50% Cr, 0.25%	
3.5% Ni, 1.50% Cr	33XX	Mo	87XX
Corrosion and		3.25% Ni, 1.20% Cr, 0.12%	
scale-resistant	30XXX	Mo	93XX
Molybdenum	4XXX	1.00% Ni, 0.80% Cr, 0.25%	
C-Mo	40XX	Mo	98XX
Cr-Mo	41XX	Silicon manganese2% Si	92XX
Ni-Cr-Mo	43XX	Boron	
Ni-Mo(1.75% Ni)	46XX	0.0005% B (min)	XXBXX

predominant alloying element. The last two or three digits usually indicate the mean carbon content divided by 100. Thus the symbol 2520 indicates a nickel steel of approximately 5 percent nickel and 0.20 percent carbon. In addition to the numbers, AISI specifications may include a letter prefix to indicate the manufacturing process employed in producing the steel. SAE specifications now employ the same four digit numerical designations as the AISI specifications, with the elimination of all letter prefixes. Some representative standard steel specifications are given for plain carbon and free machine steel in Table 2-2 and for alloy steels in Table 2-3.

NICKEL STEELS :

Nickel is one of the oldest, most fundamental steel alloying element. It has unlimited solubility in gramma iron and is higher soluble in ferrite. Nickel lowers the critical temperatures of steel and does not form any carbides which may be difficult to dissolve during austenitizing. Nickel also reduces the carbon content of the eutectoid, therefore, the structure of unhardened nickel steels contains a higher percentage of pearlite forms at a lower temperature. It is finer and tougher than the pearlite in unalloyed steels. These factors permit the attainment of given strength levels at lower carbon content, thus increasing toughness, plasticity and resistance. Nickel steels are highly suited for high strength structural steels which are used in the as-rolled condition. The 3.5 percent nickel steels with low carbon are used extensively for carburizing of drive gears, connecting-rod, bolts, studs and kingpins. The 5 percent nickel steels provide increased toughness and are used for heavy duty applications such as bus and truck gears.

TABLE-2.2 Standard -steel Specifications (9)

AISI NO*.	%C	%Mn	%P max	%S max	SAE NO.
PLAIN-CARBON STEELS					
C1010	0.08-0.13	0.03-0.60	0.04	0.05	1010
C1015	0.13-0.18	0.30-0.60	0.04	0.05	1015
C1020	0.18-0.23	0.30-0.60	0.04	0.05	1020
C1025	0.22-0.28	0.30-0.60	0.04	0.05	1025
C1030	0.28-0.34	0.60-0.90	0.04	0.05	1030
C1035	0.32-0.38	0.60-0.90	0.04	0.05	1035
C1040	0.37-0.44	0.60-0.90	0.04	0.05	1040
C1045	0.43-0.50	0.60-0.90	0.04	0.05	1045
C1050	0.48-0.55	0.60-0.90	0.04	0.05	1050
C1055	0.50-0.60	0.60-0.90	0.04	0.05	1055
C1060	0.55-0.65	0.60-0.90	0.04	0.05	1060
C1065	0.60-0.70	0.60-0.90	0.04	0.05	1065
C1070	0.65-0.75	0.60-0.90	0.04	0.05	1070
C1074	0.70-0.80	0.50-0.80	0.04	0.05	1074
C1080	0.75-0.88	0.60-0.90	0.04	0.06	1080
C1085	0.80-0.93	0.70-1.00	0.04	0.05	1035
C1090	0.85-0.93	0.60-0.90	0.04	0.05	1090
C1095	0.90-1.03	0.30-0.50	0.04	0.05	1095
FREE-MACHINING CARBON STEELS					
B1112	0.13max	0.70-1.00	0.07-0.12	0.16-0.23	1112
B1113	0.13max	0.70-1.00	0.07-0.12	0.24-0.33	1113
C1110	0.08-0.13	0.30-0.60	0.04	0.08-0.13	
C1113	0.10-0.16	1.00-1.30	0.04	0.24-0.33	
C1115	0.13-0.16	0.60-0.90	0.04	0.08-0.13	1115
C1120	0.18-0.23	0.70-1.00	0.04	0.08-0.13	1120
C1137	0.32-0.39	1.35-1.65	0.04	0.08-0.13	1137
C1141	0.37-0.45	1.35-1.65	0.04	0.08-0.13	1141
C1212	3.13 max	0.70-1.00	0.07-0.12	0.16-0.23	1112
C1213	0.13 max	0.70-1.00	0.07-0.12	0.24-0.33	1113

TABLE 2.3 [9] Alloy steel Specefication

AISI NO.	%C	%Mn	%Ni	%Cr	%MO	%V	SAE
1330	0.28-0.33	1.60-1.90					1330
1340	0.38-0.43	1.60-1.90					1340
2317	0.15-0.20	0.40-0.60	3.25-3.75				2315
2330	0.26-0.33	0.60-0.80	3.25-3.75				2330
E2512	0.09-0.14	0.45-0.60	4.75-5.25				
2515	0.12-0.17	0.40-0.60	4.75-5.25				2515
3115	0.13-0.18	0.40-0.60	1.10-1.40	0.55-0.05			3115
3130	0.28-0.33	0.60-0.80	1.10-1.40	0.55-0.75			3130
3140	0.38-0.43	0.70-0.90	1.10-1.40	0.55-0.75			3140
E3310	0.08-0.13	0.45-0.60	3.65-3.75	1.40-1075			3310
4023	0.20-0.25	0.7000.90			0.20- 0.30		4023
1037	0.35-0.40	0.70-0.90			0.20-0.30		4037
4419	0.18-0.23	0.45-0.65			0.45-0.60		4419
4118	0.18-0.23	0.70-0.90		0.40-0.60	0.08-0.15		4118
4130	0.28-0.33	0.40-0.60		0.80-1.10	0.15-0.25		4130
4140	0.38-0.43	0.75-1.00		0.80-1.10	0.15-0.25		4140
4150	0.48-0.53	0.75-1.00		0.80-1.10	0.15-0.25		4150
4320	0.17-0.22	0.45-0.60	1.65-2.00	0.47-0.60	0.20-0.30		4320
4340	0.38-0.43	0.60-0.80	1.65-2.00	0.70-0.90	0.20-0.30		4340
4720	0.17-0.22	0.50-0.70	0.90-1.20	0.35-0.55	0.15-0.26		4720
4620	0.17-0.22	0.45-0.60	1.65-2.00		0.20-0.30		4620
4626	0.24-0.29	0.45-0.65	0.70-1.00		0.15-0.25		4626
4820	0.18-0.23	0.50-0.70	3.25-1.75		0.20-0.30		4820
5120	0.17-0.22	0.70-0.90		0.70-0.90			5120
5130	0.28-0.33	0.70-0.90		0.80-1.10			5130
5140	0.38-0.45	0.70-0.90		0.70-0.90			5141
5150	0.48-0.53	0.70-0.90		0.70-0.90			5150
E52100	0.95-1.10	0.25-0.45		1.30-1.60			52100
6118	0.16-0.21	0.50-0.70		0.50-0.70		0.12	6118
6150	0.48-0.53	0.70-0.90		0.80-0.10		0.15	6150
8620	0.18-0.23	0.70-0.90	0.40-0.70	0.40-0.60	0.15-0.25		8620
8630	0.28-0.33	0.70-0.90	0.40-0.70	0.40-0.60	0.15-0.25		8630
8640	0.38-0.43	0.75-1.00	0.40-0.70	0.40-0.60	0.15-0.25		8640
8720	0.18-0.23	0.70-0.90	0.40-0.70	0.40-0.60	0.20-0.30		8720
8740	0.38-0.43	0.75-1.00	0.40-0.70	0.40-0.60	0.20-0.30		8740
8822	0.20-0.25	0.75-1.00	0.40-0.70	0.40-0.50	0.20-0.40		8822

CHROMIUM STEELS :

Chromium is a less expensive alloying element than nickel and forms simple carbides or complex carbides. These carbides chromium is soluble up to about 13 percent in gamma iron and has unlimited solubility in ferrite. In low-carbon steels, chromium tends to go into solution, thus increasing the strength and toughness of the ferrite. When chromium is present in amount in excess of 5 percent the high temperature properties and corrosion resistance of the steel are greatly improved.

The plain-chromium steels contain between 0.15 and 0.64 percent carbon and between 0.70 and 1.15 percent chromium. The low-carbon alloy steels are usually carburized. The presence of chromium increases the wear resistance of the case, but the toughness in the case is not so high as the nickel steels. with medium carbon, these steels are oil hardened and are used for spring, engine bolts, studs, axles etc.

NICKEL-CHROMIUM STEELS :

In these steels the ratio of nickel to chromium is approximately 2.50 parts nickel to 1 part chromium. The effect of nickel in increasing toughness and ductility is combined with the effect of chromium is improving hardenability and wear resistance. The combined effect of two or more alloying elements on hardenability is usually greater than the sum of the effects of the same alloying elements used separately.

The low carbon nickel chromium alloy steels are carburized. The chromium supplies the wear resistance to the case, while both alloying elements improve the toughness of the core. These are used for worm gears, piston pins etc. For heavy duty applications such as aircraft gears, shafts, and cam can be used.

MOLYBDENUM STEELS :

Molybdenum is a relatively expensive alloying element. It has a limited solubility in gamma and alpha iron, and is a strong carbide former. Molybdenum has a strong effect on hardenability as like chromium. It increases the high temperature hardness and strength of steels. This element is most often used in combination with nickel or chromium or both nickel and chromium. For carburizing applications it improves the wear resistance of the case and the toughness of the core. The plain-molybdenum steels and with low carbon content are generally carburized and are used for shafts, transmission gears, with higher carbon content they have been used for automotive coil and leaf spring. The chromium-molybdenum steels are relatively cheap and possess good hardening characteristics, ductility and weldability.

The nickel molybdenum steels have the advantages of the high strength and ductility from nickel, combined with hardening and improved mach machinability imparted by molybdenum. They have good toughness combined with high fatigue strength and wear resistance. They are used for transmission gears, chain pins, shafts and bearings. The triple alloy nickel chromium molybdenum steels have the advantages of the nickel chromium steel along with the high hardenability imparted by molybdenum. They are used extensively in the aircraft industry for the structural parts of the wing assembly.

MANGANESE STEELS :

Manganese is one of the least expansive alloying elements and is present in all steels as a deoxidizer. This element is a weak carbide former and has a moderate effect on hardenability, like nickel, manganese lowers the critical range and decease the carbon content of the eutectoid. These steels are used for gears, shaft, axles etc.

TUNGSTEN STEEL :

Tungsten has a marked effect on hardenability, is a strong carbide former, In general, the effect of tungsten in steel is similar to that of molybdenum although larger quantities are required. Since tungsten is relatively expansive and large quantities are necessary to obtain an appreciable effect, it is not used in general engineering steels. Tungsten is used particularly in tool steels.

VANADIUM STEELS :

Vanadium is the most expensive of the common alloying elements. It is a powerful deoxidizer and a strong carbide former. The low carbon chromium vanadium steels are used in the case hardening condition in the manufacture of pins and crank shafts. The medium carbon chromium vanadium steels have high toughness and strength and are used for axles and springs. The high carbon grade with high hardness and resistance is used for bearing and tools.

SILICON STEELS :

Silicon, like manganese, is present in all steels as a cheap deoxidizer like nickel, silicon is not a carbide former but rather dissolves in ferrite, increase strength and toughness. A properly balanced combined of manganese are silicon produces a steel with usually high strength and with good ductility and toughness. This silicon manganese steel is widely used for coil and leaf springs and also for chisels and punches.

STAINLESS STEELS :

Stainless steels are used for both corrosion and heat resisting application. The corrosion resisting property is due to thin, adherent, stable chromium oxide or nickel oxide film the effectively protects the steel against many corroding media. This property is not evident in the low-chromium structural steel and is apparent only when the chromium content exceeds about 10 percent.

The effect of different element in steel is shown in Table 2.2

Table 2.4 specific effects of Alloying elements in steel

Element		Effect
Chromium	i)	Increase resistance to corrosion and oxidation.
	ii)	Increase depth of hardening.
	iii)	Adds some strength at high temperature.
	iv)	Resists abrasion and wear with high carbon.
Nickel	i)	Strengthens unquenched steels.
	ii)	Toughens pearlitric ferritic steels.
	iii)	Fine grains are produced.
	iv)	coefficient of expansion is lowered.
	v)	Resistance to corrosion is increased.
Manganese	i)	Increase hardenability.
	ii)	Austenite is stabilized.
	iii)	Resistance to abrasion is increased.
Molybdenum	i)	Raises creep strength, red hardness.
	ii)	Increases corrosion resistance in stainless steel.
	iii)	Forms abrasion resisting particles.
	iv)	Cutting hardness is increased.
	v)	Hardness at high temperature is increased.
Tungsten	i)	Forms hard, abrasion resistant particles in tool steels.
	ii)	Promotes hardness and strength at elevated temperature.
	iii)	Refinement of grain structure takes place.
Vanadium	i)	Increases hardenability .
	ii)	Resists tempering and causes marked secondary hardening.
	iii)	Resistance to abrasion is increased.
	iv)	Tensile strength is increased.
Silicon	i)	Used as general purpose deoxidizer.
	ii)	Improves oxidation resistance.
	iii)	Strengthens low alloy steels.
Nickel and cromium	i)	Tensile strength is increase.
	ii)	Increase resistance to corrosion.

2.1.3 TENSILE PROPERTIES OF STEEL (16)

For the commercial importance of ferrous materials, a great deal of work has been done in correlating their tensile properties with composition and microstructure. The tensile properties of annealed and normalized steels are controlled by the flow and fracture characteristics of the ferrite and by the amount, shape and distribution of cementite. The strength of the ferrite depends on the amount of alloying elements in solid solution and the ferrite grain size. The carbon content has a very strong effect because it controls the amount of cementite present either as pearlite or as spheroidite. The strength increases and ductility decreases with increasing carbon contents because of the increased amount of cementite in the microstructure. A normalized steel will have higher strength than an annealed steel because the more rapid rate of cooling used in the normalizing treatment causes the transformation to pearlite to occur at a lower temperature, and finer pearlite spacing results. Difference in tensile properties due to the shape of the cementite particles are shown in the fig. 2.1 where the tensile properties of a spheroidized structure for a steel with the same carbon content.

The best combination of strength and ductility is obtained in steel which has been quenched to a fully martensitic structure and then tempered. The best criterion for comparing the tensile properties of quenched and tempered steel is on the basis of an as quenched structure of 100 percent martensite. Fig 2.2 shows the hardness of martensite as a function of carbon content for different total amounts of martensitic in the microstructure. The relation between tensile strength and hardness for heat treated, annealed and normalized steel is shown in the fig 2.3.

The mechanical properties of a quenched and tempered steel may be altered by charging the tempering temperature. Fig 2.4 shows how hardness and tensile properties vary with tempering temperature for an SAE 4340 steel. For low alloy steels containing 0.3 to 0.5 percent carbon which are quenched to essentially 100 percent martensite and then tempered back to any given tensile strength in the range 700 to 1400 Mpa, the common tensile properties will have a relatively fixed value, depending only on the tensile strength. Fig.2.5 shows this relationship between the mechanical properties of steel with tempered martensitic structure.

2.1.4 MATERIAL FOR BOLTS AND NUTS[11]

Bolts and Nuts may be made from several different grades of steel, as long as the finished fastener meets the specified strength requirements. The carbon and alloy constructional steel are used to produce fasteners intended for use under different service conditions.

The purchaser of steel bolts and nuts usually selects the desired strength level by specifying a grade or class in the widely used SAE and ISO specification. The producer then select a particular steel from the broad specifications. This allows the producers freedom to use the most economical material consistent with their equipment and production procedures to meet the specified mechanical properties. This situation has forced producers to adopt substantially the same manufacturing process for

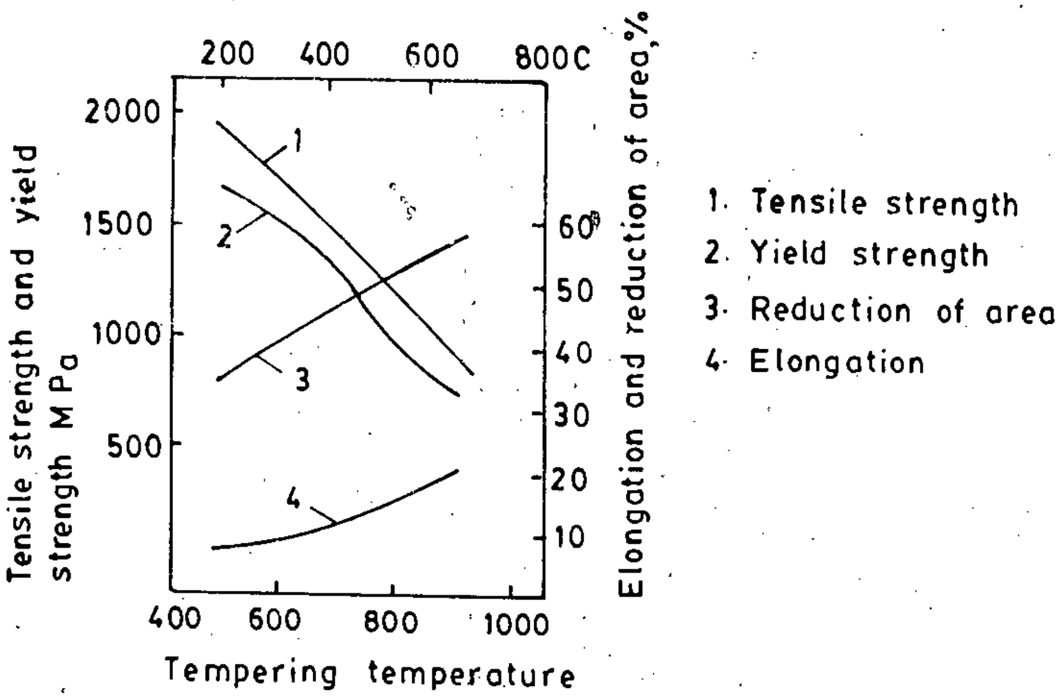


Fig. 2.4 Tensile properties of quenched and tempered steel as a functin of tempering temperature

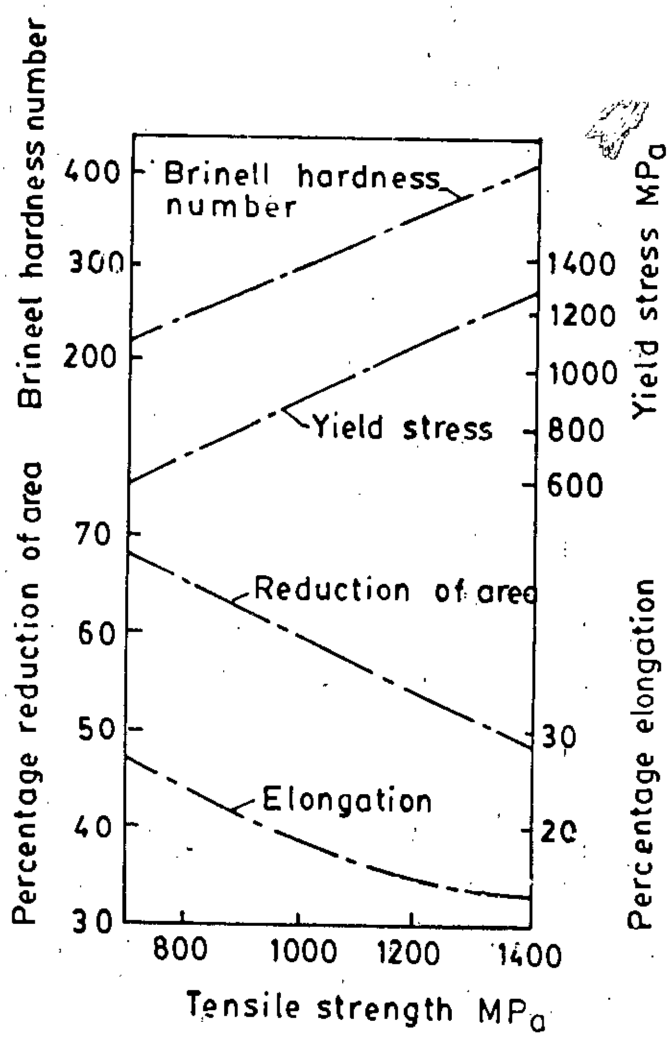


Fig. 2.5 Relationship between tensile properties of quenched and tempered alloy steel

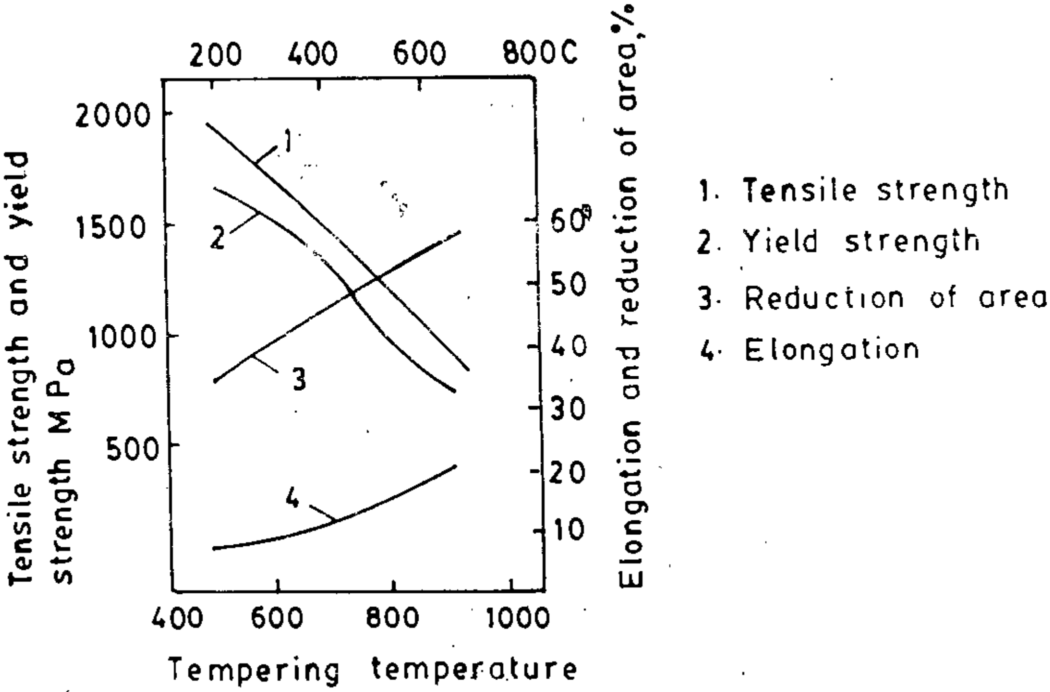


Fig.2.4 Tensile properties of quenched and tempered steel as a functin of tempering temperature

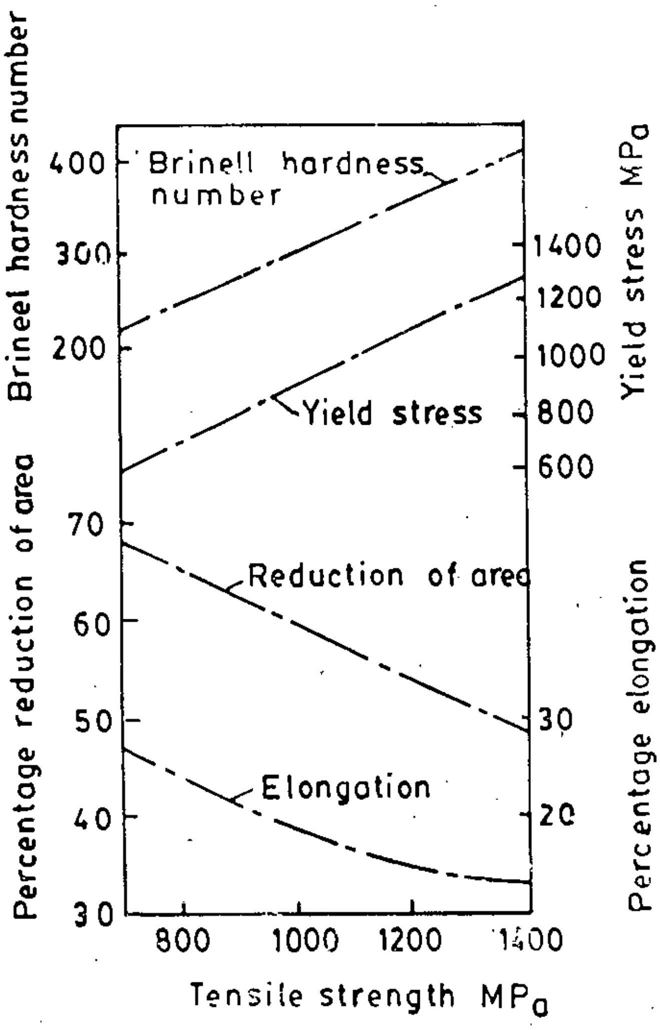


Fig.2.5 Relationship between tensile properties of quenched and tempered alloy steel

a given class of product, which has resulted in a certain degree of steel standardization.

The strength level of a bolt and nut is designated by its strength grade or property class number the greater the number, the higher the strength level. A second number, following a decimal point, is sometimes added to represent a variation of the product with in the general strength level .SAE strength grade numbers are often used for mechanical fasteners made to the united states system of inch dimensions, while the property class numbers defined in ISO recommendation are used for metric fasteners.

STEELS FOR THREADED FASTENERS

Many different low-carbon, medium carbon and alloy constructional steels are used to make all of the various strength grades and property classes of threaded steel fasteners suitable for service between -50 and + 200^0 C (-65 and + 400° F) .The chemical composition of these steels used for the grades and classes of threaded steel fasteners listed in Table 2.5 and 2.6 are given in Table 2.7 and 2.8. The following sections discuss the selection and processing of these steels for each type of bolt and nut.

BOLT STEELS

As previously noted, the producer of bolts is free to use any steel within the grade and class limitations of Table 2.7 to attain the properties of the specified grade or class in Table 2.5. As strength requirements and section size increase, hardenability becomes the most important factor.

Sometimes, specific applications require closer control, and the purchaser will consequently specify the steel composition. However, except where a particular steel is absolutely necessary, this practice is losing favor. A specific steel may not be well-suited to the fastener producers processing facilities, specification of such a steel may result in unnecessarily high cost to the purchaser.

SELECTION OF STEEL FOR NUT

The selection of steel for nuts is less critical than for bolts. The nut is usually not made from the same material as the bolt. Table 2.8 gives the chemical composition requirements for each property grade and class of steel nut is shown in Table 2.6 .

Materials listed in the above tables are not readily available in the local market. Moreover it is not easy to import these material in small quantities. Available materials are mostly unknown composition. For this reason an alternative way to use scrap material with suitable heat treatment.

2.2 SURFACE HARDENING OF STEEL

Surface hardening is a selective heat treatment in which the surface layer of a metal are hardened to a certain depth. The principal purpose of surface hardening is to increase the hardness and wear resistance of the surfaces of metal articles. At the same time, the reliability in operation of a machine component is increased along with the fatigue limit.

Table 2.5 Mechanical properties of steel bolts (11)

Strength grade or property class	Nominal diameter	Proof strees Mpa	Ksi
SAE Strength Grades			
1	$^1/_4$-$1^1/_2$ in	225	33
2	$^1/_4$- $^3/_4$ in	380	55
	>$^3/_4$-$1^1/_4$ in	225	33
5	$^1/_4$- 1 in	585	85
5.2	$^1/_4$- 1 in	585	85
7	$^1/_4$-$1^1/_2$ in	725	105
8	$^1/_4$-$1^1/_2$ in	830	120
8.1	$^1/_4$-$1^1/_2$ in	830	120
8.2	$^1/_4$- 1 in	830	120
ISO Property Classes			
4.6	5- 36 mm	225	33
4.8	1.6-16 mm	310	45
5.8	5- 24 mm	380	55
8.8	16- 36 mm	600	87
9.8	1.6-16 mm	650	94
10.9	5- 36 mm	830	120
12.9	1.6-36 mm	970	141

Table 2.6 Mechanical properties of steel nuts

Strength grade or property class	Nominal diameter	Proof strees Mpa	Ksi
SAE Strength Grades			
2	$^1/_4$-1 $^1/_2$ in	620	90
5	$^1/_4$- 1 in	830	120
		750	109
	>1- 1 $^1/_2$ in	725	105
		650	94
8	$^1/_4$-$^5/_8$ in	1035	150
	>$^4/_8$- 1 in	1035	150
	>1- 1$^1/_2$ in	1035	150
ISO Property Classes			
5	5-36 mm	570	83
5	1.6-4 mm	900	131
	4-16 mm	990	144
	20-36 mm	910	132
10	5-36 mm	1040	151

Table 2.7 Chemical compositions of steel bolts

Strenght grade or property class	Material and treatment	Composition, % C	P	S
SAE Strength Grades				
1	Low or medium-carbon steel	0.55	0.048	0.058
2	Low or medium-carbon steel	0.28	0.048	0.058
4	Medium-carbon cold drawn steel	0.55	0.048	0.058
5	Medium-carbon steel, quenched and tempered	0.28-0.55	0.048	0.058
5.2	Low-carbon martensitic steel fully killed, fine grain, quenched and tempered	0.15-0.25	0.048	0.058
7	Medium-carbon alloy steel, quenched and tempered	0.28-0.55	0.040	0.045
8.1	Drawn steel for elevated-temperature service; medium-carbon alloy steel or 1541 steel	0.28-0.55	0.040	0.045
8.2	Low-carbon martensitic steel, fully killed, fine grain, quenched and tempered	0.15-0.25	0.048	0.058
ISO Property Classes				
4.6	Low or medium-carbon steel	0.55	0.048	0.058
4.8	Low- or medium-carbon steel, partially or fully annealed as required	0.55	0.048	0.058
	Low or medium-carbon steel, cold	0.13-0.55	0.048	worked
8.8	Medium-carbon steel, quenched and tempered	0.28-0.55	0.048	0.058
9.8	Medium-carbon steel, quenched and tempered	0.28-0.55	0.048	0.058
10.9	Medium-carbon alloy steel, quenched and tempered	0.28-0.55	0.040	0.045
12.9	Alloy steel, quenched and tempered	0.31-0.65	0.045	0.045

Table 2.8 Chemical Compositions of steel nuts

Strenght grade or Property Class	Composition			
	C max	Mn min	P max	S max
SAE Strength Grades				
2	0.47		0.12	0.15
5	0.55	0.30	0.15	0.15
8	0.55	0.30	0.04	0.05
ISO Property Classes				
5	0.55		0.12	0.15
9	0.55	0.30	0.05	0.15
10	0.55	0.30	0.04	0.05

2.2.1 CARBURIZING PROCESS

Carburizing is the most satisfactory and widely used method of surface hardening of low carbon steel. It is the process of adding carbon to the surface layer of steel. Since the object of surface hardening is to obtain a hard, wear resistant surface with a tough interior, the first consideration is the selection of a low carbon (usually less than 0.20 percent carbon) steel. It is then subjected to carburization to an extent of eutectoid-hyper eutectoid composition and by subsequent heat treatment to the desired hardness. There are three general methods of carburization, each differing in technique, they are as follows:

(1) Solid or pack caburization, 2) Liquid caburization and (3) Gas caburization. The choice of the method to be followed depends upon the type of case wanted.

The depth of carburization depends on time, temperature and the type of mixture used. The pack carburization is economical and advantageous for small machine parts.

2.2.2 THEORY OF CARBURIZATION

The carburization of steel may be considered on the basis of two fundamental concepts. The first is the diffusion, influenced by the properties of the steel and concerned with the movement of carbon in the steel itself, the second deals with the source supplying the carbon and with the transfer of carbon to the steel surface. These two general concepts may be described briefly.

(1) Fick's law of diffusion: Fick's first law describes diffusion under equilibrium conditions and is stated mathematically by the following formula [2,3]

$$J_1 = D_1 \frac{dC_1}{dx}$$

Where D_1 is the diffusion co-efficient and J_1 is the resulting flux gradient. Fick's second low expresses the non equilibrium condition of diffusion where the concentration, at a point, charges with respect to time.

$$\frac{dC}{dt} = \frac{d}{dx}\left(D_1 \frac{dc}{dx}\right)$$

The value of the diffusion co-efficient is critical in any calculation dealing with carburizing or any other diffusion process. The diffusion co-efficient D is defined by

$$D = D_0 \; e^{-Q/RT}$$

Where D_0 is the temperature independent multiplicator in cm^2/sec; Q is the heat of diffusion (activation energy, i,e- the energy required for one atom to jump to a new portion in the lattice) in cal gram-atom; R is the gas constant (1.98); and T is the absolute temperature in degree Kelvin. The greater is the value of Q, the smaller is the value of D at a given temperature and hence the slower is the rate of diffusion.

(2) The equilibrium state for chemical reactions: The equilibrium state for chemical reactions may be represented by numerical constant, Kp, derived from the general expression

$$\text{Log Kp} = A/T - B$$

Where Kp is a numerical factor termed the "equilibrium constant" which is derived from the values for the concentrations of the reactants and products of a chemical reaction. The subscript P denotes the dependency of the chemical reaction on pressure. T is the absolute temperature at which the reaction takes place. A and B are constants derived for the particular reaction.

Instead of being developed in a formal way from basic principals the mechanism of carburization may be analyzed from the view point of carbon flow by stating the controlling factors. These factors may be divided for discussion in two distinct groups.

(1) Factors that control the flow carbon in iron and

(2) Factors that influence the transfer of carbon to the iron surface.

The mechanism may be explained as follows:

2.2.3 FLOW OF CARBON IN IRON

Carburizing is concerned with the solid solution of carbon in austenite. The limit of carbon content of this phase depends on the temperature and composition of the steel. The solid solution of carbon in gamma iron is an interstitial type of solid solution. As is evident from the iron and iron carbide thermal equilibrium diagram Fig. 2.6 at temperature below about 910^0 C pure iron occurs as a body centered cubic structure. Above 910^0 C there is a temperature range in which iron has a face centered cubic structure. In face centered cubic lattice, a relatively large unoccupied "void space" exist in the unit cell. Carbon being an extremely small atom can move into this void space to produce a solid solution of iron and carbon. When iron has a body centered cubic structure at lower temperature, the interstices between the iron atoms becomes much smaller and consequently the solubility of carbon in body centered cubic iron is relatively small.

The penetration of carbon into the iron forming steel will depend upon the temperature, the time at temperature, and the carburizating agent. Since the solubility of carbon in steel is greater above the AC_3 temperature, carburization takes place most readily above this temperature. Furthermore, the higher the temperature the greater the rate of carbon penetration, since the rate of diffusion is greater. The curburizing temperature is an important factor and is usually maintained within 900^0 to 925^0C for steels with alloy additions a some higher temperature is required. The depth of carbon penetration depends mostly upon the holding time.

The rate of flow of carbon in austenite depends on values for the diffusion co-efficient and characteristics of the concentration gradient. The diffusion co-efficient is a function of temperature and carbon concentration. The diffusion of carbon proceeds from the higher concentration developed from the supply sources, to the lower concentration of the core. The case depth for a carburized machine parts may be considered to be the extent of carbon concentration which on heat treatment provides the desired uniform mechanical properties. The case depth for a carburized steel is a function of temperature and time.

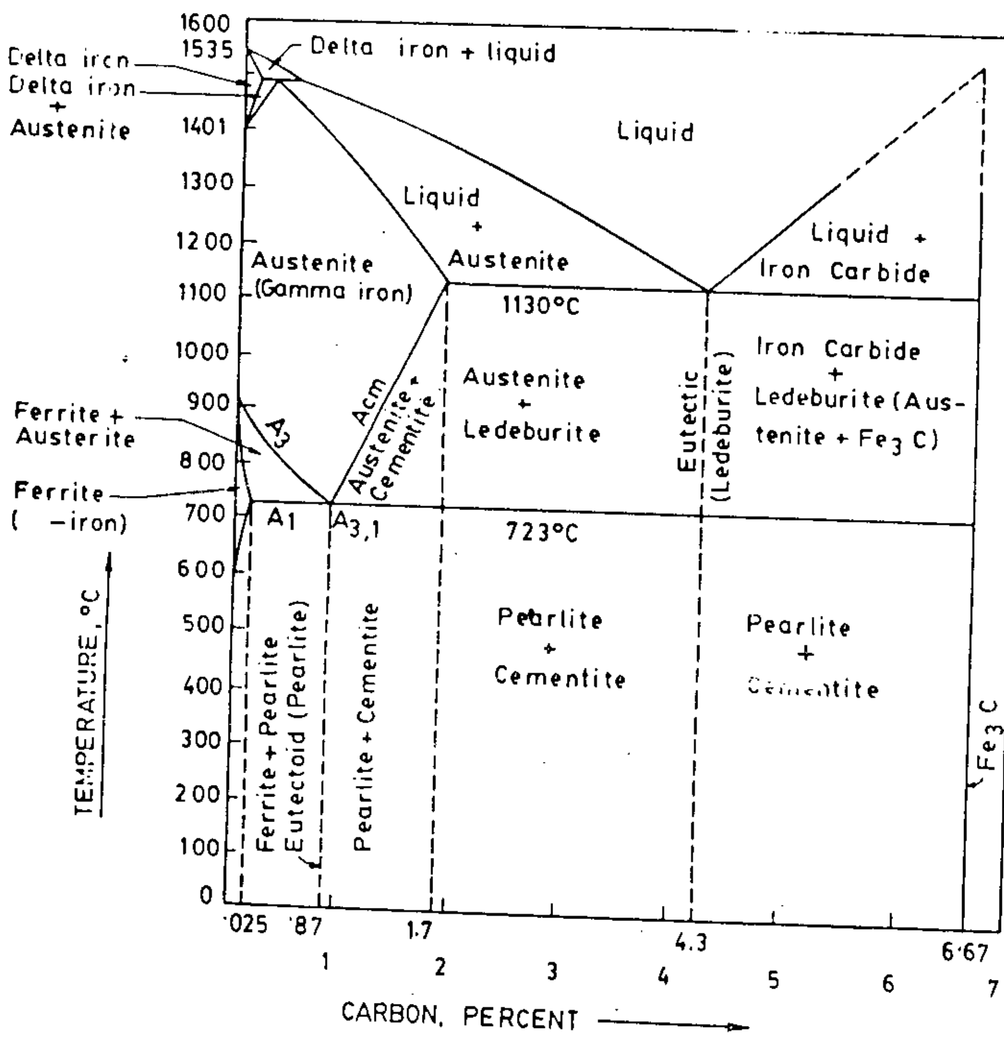


Fig 2.6 Iron and Iron carbide equilibrium diagram.

F.E. Harris[15] developed formula for the effect of time and temperature on case depth for normal carburizing.

$$Case\ depth = 31.6 \frac{\sqrt{t}}{10^{6700/T}}$$

Where case depth is in inches; t is time at temperature in hours, and T is the absolute temperature, in degrees Rankine.

For a specific carburizing temperature, the relation becomes simply

Case depth $= K\sqrt{t}$

$= 0.025\sqrt{t}$ for 1700°F

$= 0.021\sqrt{t}$ for 1650°F

$= 0.018\sqrt{t}$ for 1600°F

Diffusion co-efficient vary with the nature of the solute atoms, with the nature of the solid structure, and with changes in temperature. Higher temperatures provide higher diffusion coefficients because the atoms has higher thermal energies and therefore greater probabilities of being activated over the energy barrier between atoms. Carbon has a higher diffusion co-efficient in iron because the carbon atom is small one. Carbon atoms have higher diffusion coefficients in BCC iron than in FCC iron because the former has a lower atomic packing factor.

2.2.4 FLOW OF CARBON FROM SUPPLY SOURCE

The primary function of carburizing media is to furnish an adequate supply of carbon to the steel surface. The transfer of carbon from the source of supply to the steel is involved with reaction occuring at this surface. The carburizing agent responsible for the actual transfer of carbon is carbon compound. The external to which various carbon compound may supply carbon is related to the conditions that determine the equilibrium with the surface of the steel. The equilibrium composition of the reactants and products is a function of temperature and also of the carbon concentration at the surface.

Low carbon steels when heated to the carburizing temperature, will be completely transformed into austenite. At the carburizing temperature austenitic iron is capable of holding in solid solution an amount of carbon approaching the saturation limit of 1.7 percent. When a source of carbon, such as carbon monoxide is brought into contact with the steel in this condition, there will be transfer of carbon from the gas to the steel.

In pack carburization the carburizing compound is in reality the gas producer. In other words, the carbon monoxide is the result of the reaction between the carbonaceous compound and the oxygen from the air. The CO thus formed will be dissociated in presence of austenitic iron to give atomic carbon which will then be absorbed in it according to the following equation

$$2\,CO = (C) + CO_2$$

Where (C) is the carbon dissolved in austenite at the steel surface. Without a further supply of CO this reaction between CO, CO_2 and austenite would soon reach equilibrium and carburization would stop. Herty states that the CO: CO_2 ratio number above 24 for the above reaction to proceed and also that the rate of penetration must be above 0.01 to 0.02 mm per hour. Since, CO_2 at carburizing temperature, there is always a large amount of carbon present, the will be constantly reduced, so that there will be continous supply of CO according to the reaction

$$CO_2 + C = 2\,CO$$

This cycle continues to repeat itself, and the process of carburizing will continue as long as the proper temperature are maintained and the CO: CO_2 ratio is kept high enough. In this case the carbon will be absorbed, the concentration of carbon will be built up at the surface and will then move inward according to the simple laws of diffusion of heat or dissolved substances, i.e.- from region of higher concentration to on of lower concentration as stated earlier.

2.2.5 PACK CARBURIZING (3)

In this process solid carburizers are used. The chief carburizers for pack carburizing are activated charcoal in grains from 3.5 to 10 mm in diameter, coal semi coke, and peat coke. Carbonates are added to the charcoal to accelerate the carburizing process. They include barium carbonate and soda ash (Sodium carbonate) which are added in an amount from 10 to 40 percent of the weight of the charcoal.

Work pieces, which are to be pack carburized, are first cleaned of dirt, scale, and rust. They are then placed in a welded steel box. Their service life is about 250-300 hours .The box is covered with carburizers of 40-45 mm thick layer shown in figure 2.7. The workpieces are placed on this layer with spaces of 20-25 mm between then and the box wall. Then they are covered with a layer of carburizer, 20-25 mm thick. The upper row is covered with a layer of 40-50 mm thick. The box is closed with a layer of clay. The carburizing temperature range from 900^0 to 930^0C. The total time required on the specific depth of the carburized case. The deeper the case required, the longer the holding time should be at the carburizing temperature. The holding time is assigned on the basis of 0.1-0.12 mm per hour for cases upto 1.5 mm deep.

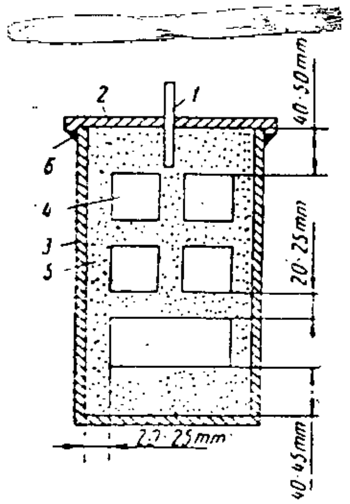


Fig 2.7 Packing workpieces in a box for carburizing.
(1-test bar, 2-cover, 3-box, 4-workpiece, 5-carburizer, 6-lufe.)

2.2.6 HEAT TREATMENT OF CARBURIZED STEEL (3,9)

The object of carburization is to develop a hard, wear resistant surface and a tough core in some moving parts. Carburization mainly provides the concentration of carbon on the surface to a case depth of about 1/16 to 1/10 inch. The case of the carburized parts is a eutcetoid or hyper eutcetoid steel and the core is a hypo-eutectoid steel of initial composition containing from 0.1 to 0.2 percent carbon. The mechanical properties of the case and of the core of the machine part will be obsiously different due to differential concentration of carbon and in the unheattreated condition the properties may not be sufficient to meet the service requirements. Hence the carburized machine parts are heat treated to get higher mechanical properties namely hardness at the surface and toughness at the core. Since the carburized mechine part gets variable carbon concentration in it, a double heat treatment is required, one for the core which is expected to be tough and the other for the case which is designed to be hard, wear resistant. Highly satisfactory results are obtained by heating the carburized machine part 100^0 F above the upper critical temperature of the core and the quenched in water. The machine part is again heated to a temperature 60^0 F above its lower critical temperature by water or oil quenching and then tempering at 150^0 to 180^0C.

2.3 HARDNESS TESTING (5,9)

Hardness is a material characteristic which can be defined in terms of resistance to deformation. The degree of hardness of a material can be manifested in a number of different ways depending upon the conditions to which the material is subjected. In metals, the most commonly used measure of hardness depends upon the resistance to penetration by much harder body. Hardness may also be manifested as a resistance to abrasion or wear, as a resistance to cutting, as a resistance to crushing, as a resistance to deformation as in tension or compression. The best example of the correlation between hardness and other mechanical properties is provided by quenched and tempered steels. Where a hardness measurement permits a good estimate of most of the other mechanical properties. Hardness test are especially well adopted to checks of uniformity of product, because of the great ease with which they can be made.

There are different. types of hardness test most widely used as follows:-

1) Brinell hardness test

2) Rockwell hardness test

3) Vickers hardness test

2.3.1 BRINELL HARDNESS TEST

The Brinell hardness tester usually consist of hand operated vertical hydraulic Press, designed to force a ball indentor p into the test specimen. Standard procedure requires that the test be made with a ball of 10 m m diameter under a load of 3000 kg for ferrous metals or 500 kg for nonferrous metals. For ferrous metals the loaded ball is pressed into the test specimen for at least 10S, for non ferrous metals the time is 30S. The diameter of the impression produced is measured by means of microscope containing scale.

The Brinell hardness number (HB) is the ratio of the load in kilograms to the impressed area in square millimeters, and is calculated from the following formula.

$HB = L / (\pi D/2)(D-\sqrt{D^2-d^2})$

where L = test load, kg

D = diameter of ball, mm

d = diameter of impression ,mm

The Brinell hardness number followed by the symbol HB. Standard test conditions using a ball of 10 m m diameter and a load of 3000 kg applied for 10 to 15 S . For example, 75 HB 10/500/30 indicates Brinell hardness of

75 measured with a ball of 10 mm diameter and a load of 500 kg applied for 30S.

2.3.2 THE ROCKWELL HARDNESS TEST

The Rockwell hardness test, like Brinell test, measure that aspect of hardness which manifests itself as a resistance to penetration. Because of its simplicity, and accuracy. The Rockwell test is more widely used today than any other type of hardness test. A wide variety of testing conditions is available, which permits over a wide ranges of hardness and also permits testing of very thin materials.

This hardness test uses a direct reading instrument based on the principle of different depth measurement. The test is carried out by slowly raising the specimen against the indentor until a fixed minor load has been applied. This is indicated on the dial gauge. Then the major load is applied through a loaded lever system. After the dial pointer comes to rest, the major load is removed and, with the minor load still acting, the rockwell hardness number is read on the dial gauge. Since the order of the number is reversed on the dial gauge, a shallow impression on a hard material will result in a high number while a deep impression a soft material will result in a low number.

There are two Rockwell machines, the normal tester for relatively thick sections, and the superficial tester for thin section. The minor load is 10 kg on the normal tester and 3 kg on the superficial tester. A variety of indentors and loads may be used, and each combination determines a particular Rockwell Scale. Indentors include hard steel balls 1/16, 1/8,1/4 and 1/2 inch diameter and a 120^0 conical diamond (brale) Point. Major loads are 60, 100 and 150 kg on the normal tester and 15, 30 and 45 kg on the superficial tester.

The most commonly used Rockwell Scales are B (1/16 inch ball diameter and 100 kg load) and the C (diamond indenter and 150 kg load) both obtained with the normal tester. Because of the many rockwell scales the hardness number must be specified by using the symbol HR followed by the letter designating the scale and preceded by the hardness numbers . For example 82 HRB means Rockwell hardness of 82 measured on the B Scale (1/16 in ball and 100 kg load).

2.3.3 VICKERS HARDNESS TEST:

The Vickers hardness test is another class of tests which measures resistance to penetration. It is similar in principle to the Brinell test, but utilizes different indenter and different magnitudes of loads. The indenter used in the vickers test is a square based diamond pyramid, and the hardness value obtained when using this penetrator is frequently referred to as the diamond pyramid hardness. The angle between opposite faces of the pyramid is 136 degrees.

In making the vickers test, the indenter is forced into the specimen and the diagonals of the square impression measured and averaged. The diamond pyramid hardness number is then calculated as the ratio of the applied load to the surface area of the impression. For the 136 degree square based pyramid the hardness can be calculated from the following formula.

Diamond pyramid or vickers hardness $HV=1.854\ P/d^2$ where, P is the load in kilograms applied in making impression and d is the average of the measured diagonals of the indentation expressed in millimeters.

Tables are available to convert the measured diagonal to vickers pyramid hardness number. Specimen surface preparation is very important for the vickers test, and for very light loads should approach a metallographic polish. Here the load range is usually between 1 and 120 kg.

The vickers test is especially useful at high hardness levels because the diamond indenter deforms very little as compared to the balls used in the Brinell test. Up to about 300 Brinell hardness, Vickers number and Brinell numbers and particularly indentical, Above 300, the Vickers number become higher, partially because of the deformation of the Brinell ball of the brinell impression which causes the 136 degree conical impression is used.

2.3.4 HARDNESS CONVERSION TABLES

The choice of test for a particular hardness determination will depend on a number of factors, including the size of specimen and the hardness level. Frequently it may be desirable to convert a hardness reading obtained on one scale, say Rockwell 'C' to some other scale, say Brinell hardness, for purposes of comparison with of the data. Hardness conversion tables have been prepared for this purpose. The society of Automotive Engineers and American society of testing and materials have jointly prepared a set of conversion data for steel harder than 220 BHN. which is shown in the Table 2.9.

Table 2.9 Hardness & Tensile strength conversion

Hardness					Tensile strength	
		Rockwell Hardness				
Vickers Hardness	Brinell No.	C scale 150 kg load	A scale 60 kg load	B scale 100kg load	Tons per square in	Kilos per sq. m.m.
100	95		43	54	23	36
120	115		47	65	27	42
140	135		50	77	31	49
160	155		53	83	35	55
180	175		56	89	40	63
200	195		59	94	44	69
220	215		60	97	48	76
240	235	20	61	100	52	82
260	255	24	63		57	90
280	275	27	64		61	96
300	295	30	66		65	102
320	310	32	67		70	110
340	325	34	68		74	117
360	345	36	69		77	121
380	360	39	70		81	128
400	380	40	71		85	134
420	395	42	72		88	139
440	415	44	73		91	143
460	430	45	73		95	150
480	445	47	74		98	154
500	460	48	75		101	160
520	475	49	75		104	164
540	490	50	76		107	169
560	505	51	76		110	173
580	520	52	77		112	176
600	535	54	77		115	181
620	545	55	78		117	184
640	560	56	78		120	189
660	570	57	79		122	192
680	585	57	80		126	198
700	595	58	81		129	203
725	605	59	81		131	206
740	630	61	82		136	214
800		62	82		140	220
850		63	83		145	228
900		65	83		150	236
950		66	84			
1000		68	84			
1100		69	85			
1200		70	87			

CHAPTER-3
DIFFERENT ASPECTS OF THREAD

3.1 Kinds of threads [17]

The sharp crest and root of the V-thread, Fig 3.1(a) occasionally cut on lathes are undesirable. The thin material is easily injured because the concentration of stress at the root of the thread is large. William sellers proposed (1864) the form in fig 3.1(b), with flat crest and root, which particularly removes the weakner of the v thread. The Sellers thread was the U.S standard for many years.

The whitworth thread (1841), fig 3.1(c) with round crests and roots, has been the standard in Britain. It has better fatigue strength, because of the rounded root, than the seller thread.

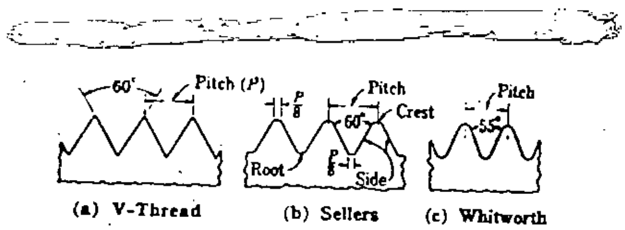


Fig. 3.1 Thread forms for screws.

The current U.S standard, shown in Fig 3.2 is in agreement with the international (USA, Britain, Canada) Unified standard. The standard has the 60° thread angle of the old American standard and the optional rounded root of the British standard for an external thread. The crest may be either flat or rounded, as shown. There are similar choices for the internal thread, Fig 3.1(b)

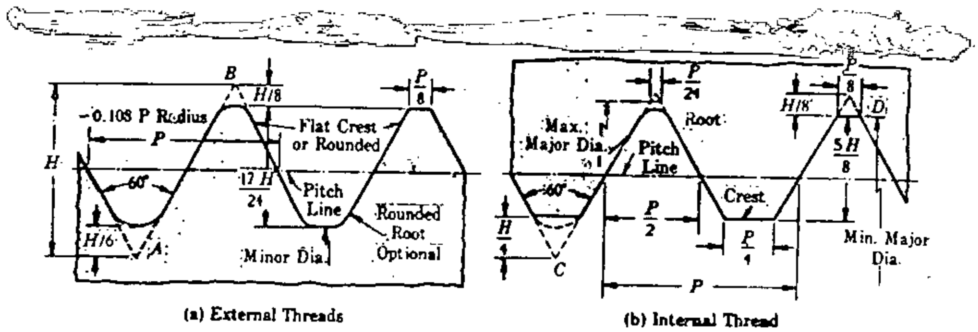


Fig-3.2 : Unified screw thread H=0.866p and P=Pitch.

The major diameter is the diameter of the imaginary cylinder that bounds the crests of an external threads and the roots of an internal thread. It is the largest diameter of the screw thread. This dimension has been called the outer diameter. The size of a screw is its nominal major diameter. The minor diameter is the diameter of the imaginary cylinder that bounds the roots of an external thread or the crests of an internal thread. This dimension has been commonly called the root diameter. The pitch P is the axial distance from a point on a screw to a corresponding point on the adjacent thread,

$$P\ (\text{inches}) = 1\ /\ \text{Number of thread per inch}$$

The lead is the distance in inches a screw thread (a helix) advances axially in one turn. On a single thread screw, the lead and pitch are identical, on a double thread screw, the lead is twice the pitch, on a triple thread screw, the lead is three times the pitch.

3.2 Standard threads

There are a number of standard threads, some quite specialized, Table 3.2 gives certain data for some widely used threads. The coarse thread series (designated UNC) is recommended for generally use, where jar and vibration are not important factors, where disassembly of parts is frequent .The fine thread series (designated UNF) is frequently used in automotive and aircraft work. Especially where Jar and vibration are present and where fine adjustment is required.

The extra fine thread series (designated UNEF) is particularly useful in aeronautical equipment. It is suitable where thin walled material is to be threaded, where fine adjustment are required and where jar and vibration are excessive.
The 8 thread series (designated 8UN), Table 3.2 is used on bolts for high pressure Pipe flanges, cylinder lead studs, etc. There are several constant series, for example, 12 UN, 16UN, 20UN (under fine, Table 3.3).

3.3 Methods of thread production

There are following four methods of thread production.

1. Cutting
2. Rolling
3. Casting
4. Grinding

Table 3.1 EXTRA-FINE AND 8-THREAD SERIES [17]

Unified and American Standard

EXTRA-FINE SERIES(NEF AND UNEF)					8-THREAD SERIES (8N AND 8 UN) (PRIMARY SIZES)		
Size	Basic Major Dia. in	Th In (tpi)	Minor Dia Ext. Th	Stress Area As sq. in.	Size	Minor Dia Ext. Th.	Stress Area As sq. in.
12	0.2160	32	0.1777	0.0270	1	0.8466	0.606
1/4	0.2500	32	0.2117	0.0379	1 1/8	0.9716	0.790
5/16	0.3125	32	0.2742	0.0625	1 1/4	1.0966	1.000
3/8	0.3750	32	0.3367	0.0932	1 3/8	1.2216	1.233
7/16	0.4375	28	0.3937	0.1274			
					1 1/2	1.3466	1.492
1/2	0.5000	28	0.4562	0.170	1 5/8	1.4716	1.78
9/16	0.5625	24	0.5114	0.214	1 3/4	1.5966	2.08
5/8	0.6250	24	0.5739	0.268	1 7/8	1.7216	2.41
11/16	0.6875	24	0.6264	0.329			
3/4	0.7500	20	0.6887	0.386	2	1.8466	2.77
					2 1/4	2.0966	3.56
13/16	0.8125	20	0.7512	0.458	2 1/2	2.3466	4.44
7/8	0.8720	20	0.8137	0.536	2 3/4	2.5966	5.43
15/16	0.9375	20	0.8762	0.620			
1	1.0000	20	0.9387	0.741	3	2.8466	6.51
1 1/16	1.0625	18	0.9943	0.799	3 1/4	3.0960	7.6738
					3 1/2	3.3466	8.96
1 1/8	1.1250	18	1.0562	0.901	3 3/4	3.5966	10.34
1 3/16	1.1875	18	1.119	1.009	4	3.2466	11.81
1 1/4	1.2500	18	1.1818	1.123	4 1/4	4.0966	11.38
1 5/16	1.125	18	1.2448	1.244	4 1/2	4.3466	5.1
1 3/8	1.3750	18	1.3068	1.370	4 3/4	4.966	16.8
1 7/16	1.4375	18	1.3693	1.503	5	4.8466	18.7
1 1/2	1.5000	18	1.4318	1.54	1 1/4	5.0966	20.7
1 9/16	1.5625	18	1.4943	1.76	5 1/2	5.3466	22.7
1 5/8	1.6250	18	1.5568	1.94	5 3/4	5.5966	24.9
1 11/16	1.6875	18	1.6193	2.40	6	5.8466	27.1

TABLE 3.2
UNIFED AND AMERICAN SCREW THREADS-COARSE AND FINE (17)

SIZE	BASIC MAJOR DIA in	COARSE (UNC)			FINE (UNF), AND 12 UN		
		Th. In. (tpi)	Minor Dia Ext. Th	Stress Area.A, sq.in	Th In	Minor Dia Ext. Th.	Stress Area, As sq. in.
0	0.0600				80	0.0447	0.0180
1	0.0730	64	0.0538	0.00263	72	0.0560	0.0278
2	0.0860	56	0.0641	0.00370	64	0.0668	0.0394
3	0.0990	48	0.0734	0.00487	56	0.0771	0.0523
4	0.1120	40	0.0813	0.00604	48	0.0864	0.0661
5	0.1250	40	0.0943	0.00796	44	0.0971	0.0083
6	0.1380	32	0.0997	0.00909	40	0.1073	0.0101
8	0.1640	32	0.1257	0.0140	36	0.1299	0.0147
10	0.1900	24	0.1389	0.0175	32	0.1517	0.0200
12	0.2160	24	0.1649	0.0242	28	0.1722	0.0258
1/4	0.2500	20	0.1887	0.0318	28	0.2060	0.0364
5/16	0.3125	18	0.2443	0.0524	24	0.2614	0.0580
3/8	0.3750	16	0.2983	0.0775	24	0.3239	0.0878
7/16	0.4375	14	0.3499	0.1063	20	0.3762	0.1187
1/2	0.5000	13	0.4056	0.1419	20	0.4387	0.1599
9/16	0.5625	12	0.4603	0.182	18	0.4943	0.203
5/8	0.6250	11	0.5135	0.226	18	0.5568	0.256
3/4	0.7500	10	0.6273	0.334	16	0.6733	0.373
7/8	0.875	9	0.7387	0.462	14	0.7874	0.509
1	1.0000	8	0.8466	0.606	12	0.8978	0.663
1 1/8	1.125	7	0.9497	0.763	12	1.0228	0.856
1 1/4	1.2500	7	1.0747	0.969	12	1.1478	1.073
1 3/8	1.375	6	0.1705	1.115	12	1.2728	1.315
1 1/2	1.5000	6	1.2955	1.405	12	1.3978	1.581
1 3/4	1.7500	5	1.5046	1.90	12	1.6478	2.1853
2	2.0000	4 1/2	1.7274	2.50	12	1.8978	2.8892
1 /4	2.2500	4 /2	1.9774	3.25	12	2.1478	3.6914
2 1/2	2.5000	4	2.1933	4.00	12	2.3978	4.5916
2 3/4	2.7500	4	2.4433	4.93	12	2.6478	5.5900
3	3.000	4	2.6933	5.97	12	2.8978	6.6865
3 1/4	3.2500	4	2.9433	7.10	12	3.1478	7.8812
3 1/2	3.5000	4	3.1933	8.33	12	3.3978	9.1740
3 3/4	3.7500	4	3.4433	9.66	12	3.6478	10.564
4	4.0000	4	3.6933	11.08	12	3.8978	12.054

3.3.1 Cutting

External and internal thread cutting are performed on lathe. Diameter of the work piece is the main considerable factor in this method. Thread cutting is done by using the following cutting tools.

1. Single point threading tools.
2. Chasers
3. Taps
4. Treading dies
5. Die heads
6. Thread milling cutters
7. Thread generating cutters
8. Modern machining process (EDM, Ultrasonic etc)

3.3.1.1 Single point threading tool

Mainly single point tool is used for thread cutting on a lathe. These tools are used to cut external and internal threads. They are grouped in to three classes such as follows.

(a) Flat (flank type) single point tools: These types of tool are mainly used to cut external thread with considerable lead angle with the pitch P. Generally by the lead angle is defined as

$$\tan\alpha = P / \pi \, dp$$

Where α= lead angle

P=Pitch

dp=Pitch diameter (Fig. 3.3a)

(b) Black single point tools: This type of tool is clamped for operation in a special holder. The relief angle is given to this type of tool by indenting the position of the tool in the holder. Block type tool can be employed only for thread with small lead angle since it is impossible to provide different relief angle on the two sides of the profile (Fig 3.3b.)

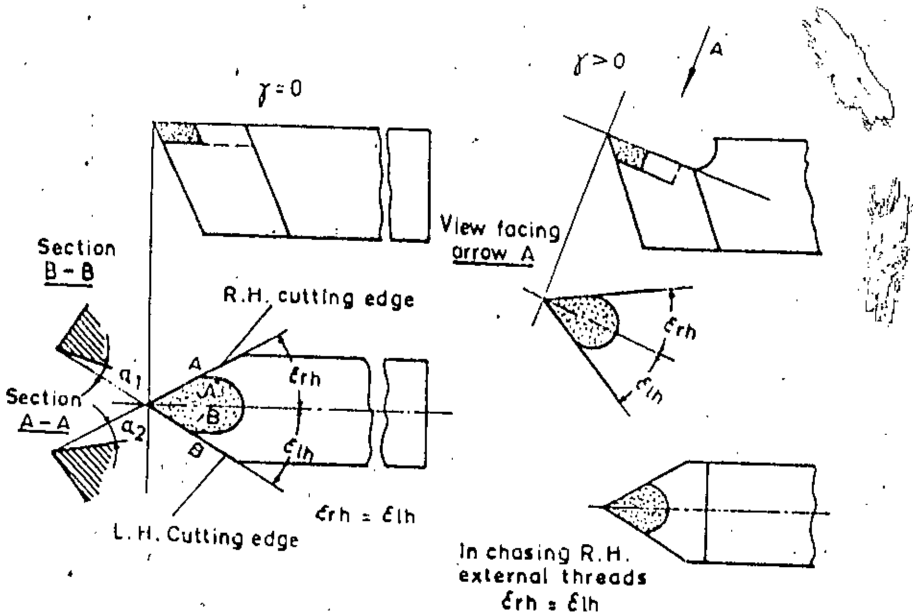
(c) Circular single point tools: These tools are more widely used than the preceding type because they are easier to manufacture and their profile can be ground in a thread grinder. Circular tools for external threads are usually of the arbor type (with a mounting hole). They are clamped in a special type of holder. (Fig 3.3c)

2.3.3.1.2 Chasers

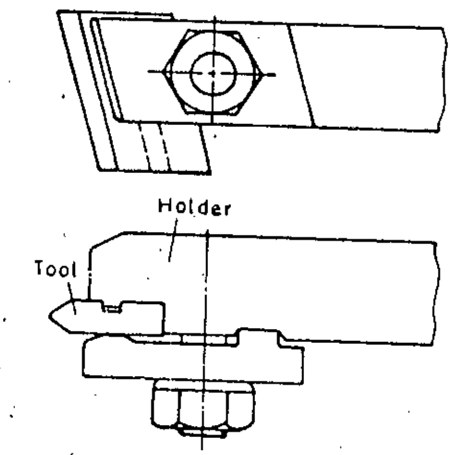
Multiple rib threading tools are called chasers. A chamfer, at an angle is provided at the entering end of a chaser to distribute the cutting action over several teeth (2 or 3) of the chaser. The sizing action cleans up the thread cut by the chamfer. It is used for making external thread as well as internal thread. It has three types such as (a) Flat or shank type, (b) Block type and (c) Circular type. Flat and Block type chaser are not commonly used. But circular type chaser is most popular and widely used.

3.3.1.3 TAPS

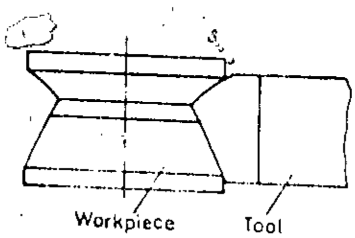
A tap is used to cut internal threads. A tap is a screw on which longitudinal straight or helical flutes have been milled to form cutting edges. It operates with two simultaneous motions, rotation on of the work or tap on which the cutting edges are placed. Chips are removed in several layers by different cutting edges situated at different diameters on tapping to cover the full thread depth. Usually set



(a) Flat (Shank type)



(b) Block type



(c) circular type

Fig.3.3 Single point threading tools.

of two or three taps are used successively in practice to cover the larger thread depth .(Fig. 3.4)

The principle parts and constructional elements of a tap are:

(1) The thread length: It is the part of the tap on which thread is cut. It can be divided into two parts:

(a) The chamfer or cutting section: It is the front tapered end of the tap and services for rough cutting of the thread.

(b) The sizing section cleans up the thread by the chamfer.

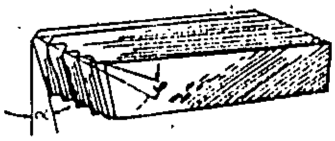
(2) The shank: It is the portion of the tap by which it is held in a chuck on tap wrench; the square serves for transmitting the torque to drive the tap.

(3) Flutes: Lands and core: Flutes is used for accomodating the chips. Core is the central position of the tap be the flutes which joins the lands. Tap can be classified into the following main types; hand, nut, machine master, die, adjustable and collapsible.

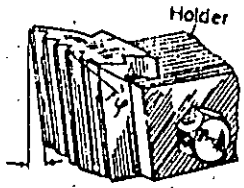
3.3.1.4 Threading Dies

A threading die is an internal thread tool used to cut external screw threads by screwing on the work piece. Threads are usually cut in on pass. Threading dies may be solid or split, they may be round, square or hexagonal, spring or twopiece adjustable dies for a hand stock. It is used in the making of external thread. There are following types of threading dies as follows.

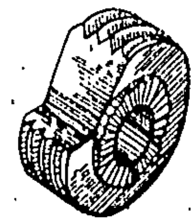
(a) Round threading dies have short coming and many attempts have been made to improve their construction. Dies with inclined clearance holes push the chips forwards facilitating their disposal and improving the cutting conditions (Fig.a)



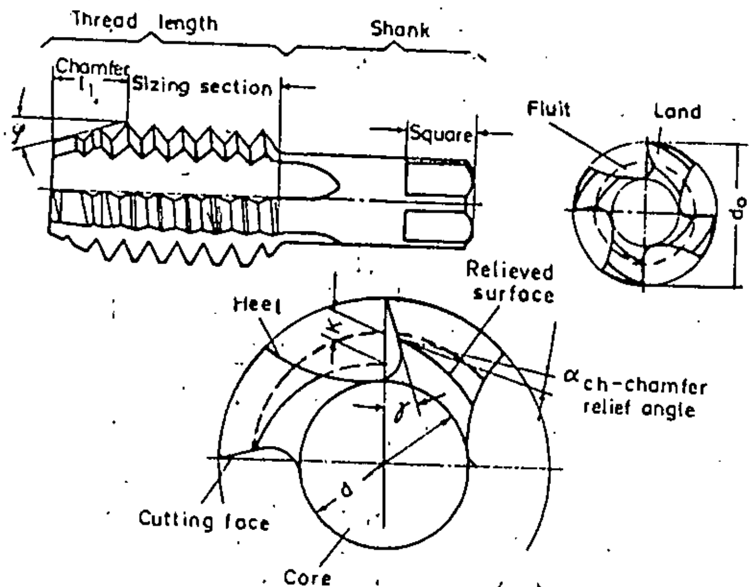
(a) Flat shank type chaser



(b) Block type chaser



(c) Circular chaser



(d) Tap and its constructional eleme

Fig. 3.4 Thread chasers and Tap.

(b) Hexagonal and square dies are convenient in creating operations since they can be driven with an ordinary wrench (Fig.b)

(c) Spring dies find application in automatic screw machines because they do not become clogged with clips as much as ordinary round dies.(Fig C)

(d) Two piece adjustable dies are used to cut coarse thread by hand in several passes. Such dies permit the diameter of the thread cut to be changed by adjusting the dies.(Fig. d)

3.3.1.5 Die Heads

There are two types of thread cutting die heads such as follows:

(1) Self opening die heads: It can be automatically withdraw from the work piece at the completion of the thread. In respect to their arrangement and construction of their closures, they are three types of self opening die head in use.

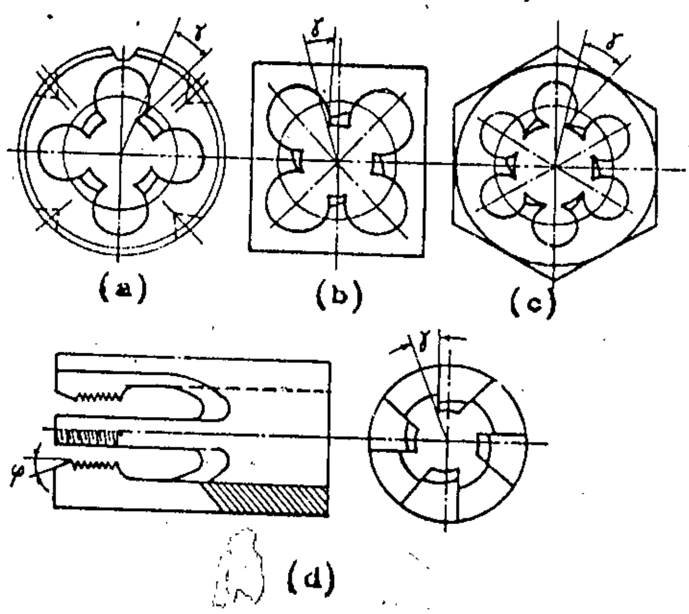
(a) Die heads with flat radial chasers: They are simpler to manufacture but their chasers can not withstand many regrinds for sharpening. These heads are being superseded at the present time by other design.(Fig.e)

(b) Die heads with tangent chasers: They are of more advanced construction and their chasers can be sharpened many more time because of their great length .(Fig.f)

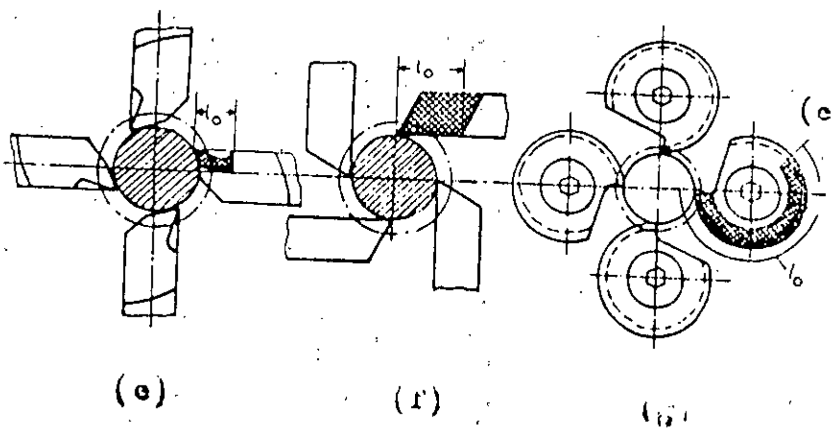
(c) Die heads with circular chasers: In respect of regrinding, die heads with circular chasers are better with their construction. They are designed on the lines of a circular form tool and they allow the greatest number of regrinds. (Fig.g)

(2) Slid adjustable die heads:

Solid adjustable die heads provide only for mounting and adjusting the chasers. The head is not opened and chasers are not with drawn at the end of the thread. Only the self opening die heads are used to any great extent.



(a) Round Die
(b) Squeare Die
(c) Hexagon Die
(d) Spring Die



(e) Die head with flat radial chaser
(f) Die head with tangential chaser
(g) Die head with circular chaser

Fig. 3.5 Thread cutting dies and die heads.

3.4 SPECIFICATION

The standard method for designating a screw thread is to specify in sequence the normal size, number of thread per inch, thread series, symbol and thread class, (External or internal) symbol, and direction of thread, Right hand or left hand.

Identification symbols for use one drawing, shops and storeroom, should be according to the following examples.

(a) An externally threaded part, 1 in diameter, unified coarse thread, 8 thread per inch, class 2 A tolerance, Right hand thread is designated as follows-

1"-8 UNC - 2A

(b) An internal thread 1 in diameter, unified thread, 12 thread per inch, class 2 B tolerance, left hand thread is designated as follows-

1" -12 UNF - 2 B -LH.

3.5 Initial tension and tightening torque [17]

The stress or load induced by the tightening operation is called the initial tension. There will be large variation of the induced stress because of the way the threads are finished, their lubrication and the other variables of the application. The relation between the applied torque T in -lb and initial tension Fi- lb proposed by Maney is

$$T = CDF_i \quad \text{in -lb} \qquad \text{.........(1)}$$

Where D is the nominal bolt size. C is the torque coefficient It is taken as a constant for a particular set of conditions. C = 0.2 is taken for unlubricated bolt and C = 0.15 is taken for lubricated Bolt.

3.6 Proof stress

Bolt design is performed with a proof load or proof stress σp. In general, a proof load is some load agreed to buy the purchaser and vendor as a capacity to be met. For bolts and screws, there seems to be no unique definition.But the proof stress σp in the SAE specification is usually close to 96% of the yield strength.

In the design procedure, it is necessary to at first decide upon proof stress. From the proof stress, the next decision is taken in the initial tightening stress. In structure, the tendency is to tighten the bolt to or beyond the yield, $\sigma i \cong \sigma y$, in high strength material. On the other hand, a review of the literature suggests that on initial stress some what less than σp or σy typical values for bolts to be subjected to a tensile load are $\sigma i \cong 0.9\ \sigma p$

(When proof stress available)

or $\sigma i \cong 0.85\ \sigma y$

(When proof stress is not available)

Having decided upon a suitable σi, the initial tightening force is $Fi = \sigma i\ As$, then equation (1) with proper value of C, can be used to estimate the tightening torque.

CHAPTER - 4

EXPERIMENTAL PROCEDURE

4.1 Selection of raw material of the Bolts and Nuts

Raw material of the Bolts and Nuts are selected according to the following test performed on local and imported samples.

4.1.1 Chemical Analysis :

In this analysis different samples of foreign and local are taken, then chip in the fine form is prepared using lathe machine. Two sample of one gm are taken for the carbon analysis. 0.5 gm of two sample are taken for Cr, 2gm of two sample are taken for Mo. These samples are then analyzed frequently using the following method.

4.1.1.1 Determination of total carbon by strohlein apparatus (combustion method)

This is a very quick method of determining total carbon in ferrous materials. Here carbon is oxidized at a high temperature in a stream of dry and pure oxygen to yield CO_2. This CO_2 is absorbed in saturated KOH solution. The decrease in volume of the gas of the absorbed in saturated KOH solution. The decrease in volume of the gas of the absorption is read directly on a scale as percentage of carbon, of the making due corrections in the volume for the change in temperature and pressure.

Procedure

The combustion furnace is bring to the proper temperature 1000-1050^0 C for iron and plain carbon steels and 1150-1200^0 C for alloy steels. The combustion boat alongwith the 1 gm of sample (fine drillings) is introduced into the hot zone of the combustion tube. The oxygen for combustion is supplied from a gas cylinder to the combustion tube at a constant pressure which is dried by passing through concentrated H_2So_4.

Then necessary link is made between the furnace and the burette through cock. The rate of reaction observed from the descent of liquid in the burette, reaction generally takes 2-3 minutes. The gas is collected unit the measuring burette nearly filled. The level is adjusted. Then the cock is opened in such a way as to connect the absortion vessel (filled with KOH solution) with the measuring burette. The gas is passed thrice into the abosorption vessel. The remaining gas is collected in the burette. The levels are again adjusted with the help of the leaving bottle and the percentage of carbon was then directly read on the scale of the burette.

4.1.1.2 Chromium

Estimation of Cr in steel permagnate method.

2 gms of the sample are dissolved in 70 ml of dil H_2So_4 (1.7) and when decomposition is complete, 30 ml of HNo_3 (S.G.1.42) are boiled until no

Boiled until the excess $KMno_4$ is decomposition (about 10-15 mins). If the solution is still pink added a few crystals of $MnSO_4$ and boiled for another 10 minutes. Filtered and washed the residue with hot water. The filtrate is cooled and titrated with N/10 $FeSO_4.(NH_4)_2$ $6H_2o$ solution and N/10 $KMno_4$ solution.

The ferrous ammonium surlfate solution is added until the yellow dichromate color is replaced by a pale green colour. Potassium permaganate was then added to a faint pink tint that persists without fading after the solution has been stirred for 60 seconds. 1 ml of N/10 $Fe(NH_4)So_4$ $6H_2o$ solution equals 0.08668% Cr on 2 gm sample. Cr determinations by this method, a small blank equal to 0.4-0.5 ml of N/10 $FeSO_4$ (NH_4) $6H_2o$ is found irrespective of the amount of sample initially taken.

4.1.1.3 Molybdenum

LEAD MOLYBDENUM METHOD

2 gms of the steel are dissolved in 30-50 ml of conc.HCl and of the reaction is complete, it is oxidized with about 5 ml of conc HNO_3. The solution is evaporated to a syrup and is taken transferred to a dropping funnel. About 200 ml of hot 20% NaoH solution is taken in a 600 ml conical flask and the solution is run dropwise into the flask with continous stirring the funnel being washed into the flask several times. The mixture is cooled, diluted to 50 ml and filtered, washing with 1.0-1.5% NaoH solution three times.

The solution is then neutratized with HCl and an excess of about 1 ml was added (indicator, methyl orange). It is then heated to boiling and 5 ml of 8% lead acetate solution are added, followed by sufficient hot ammonium acetate to change the red color to a very definite yellow. The solution is boiled and allowed to stand for a while. It is then filtered through pulped washed with hot water. It is then ignited at a low red heat and weighed as $PbMoO_4$ containing 26.15% Mo.

4.1.2 Microstructure Study

Specimens are prepared from local and imported samples. Following steps that have been carried out for the preparation of specimen.

1. Polishing on emary Paper
2. Rinsing in water
3. Polishing in rotating disc covered with a suitable pad with a suspension of a polishing powder (alumina) in water.
4. Wash under tap
5. Drying on a soft cloth
6. Eteching with a suitable etchant solution containing 95% H_2o and 5% HNo_3
7. Washing in a stream of running water and subsequently in alcohol or acetone.

The microstructures of these specimens were examined by optical microscope and photographs on the microstructure of each specimen are taken using a photomicroscope.

4.1.3 Microhardness Study

The preparation of specimen are same as the specimen for microstructure without etching. The procedures followed are as follows.

1. Polishing on emary paper.
2. Rinsing in water.
3. Polishing in rotating disc covered with a suitable pad in pregnated with a suspension of a polishing powder (alumna) in water.
4. Washing under tap.
5. Washing with ethyl alcohol.
6. Drying on a soft clean cloth.

After preparation of specimen vickers hardness is tested by a microhardness testing machine. Hardness is tested at different areas of the specimen cutting at 45^0 and 90^0 angle to the axis and the average of these are taken.

4.2 Analysis of the different parameters of the thread of the local and imported Nuts and Bolts.

For this analysis different local and foreign samples are taken. Different parameters such as pitch, thread per inch, finishing of thread are checked for both local and imported samples. Bolts and nut of both types are cut and its photograph are taken.

4.3 Manufacturing of the bolts and Nuts with the desired properties.

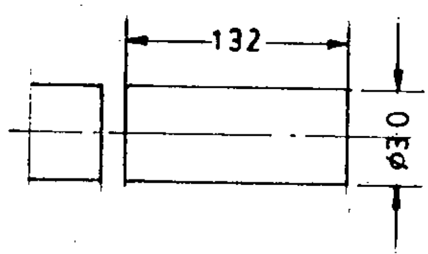
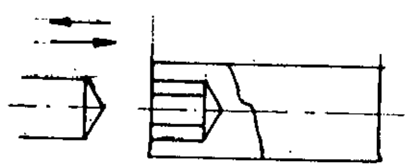
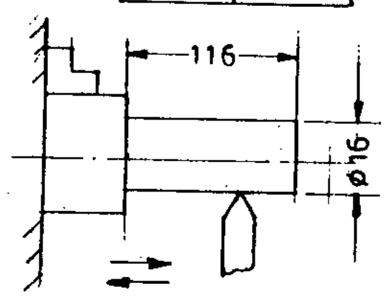
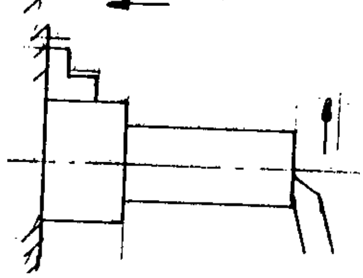
Few bolts and Nuts are manufactured on experimental basis.

4.3.1 Machining operation

Locally available medium carbon steel is taken for allen key bolt. Same material of hexagonal shape is teken for nut. The machining operations are performed on it. Manufacturing process is described in the process sheet 4.1 and 4.2.

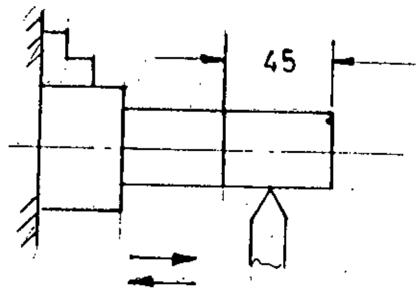
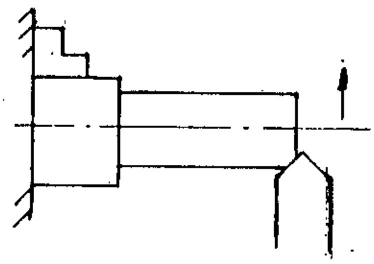
Process Sheet 4.1

Operation Sheet for Allen Key Bolt Manufacturing.

Operation No.	Description	Sketch	Machine Tool
1.	Cutting of MS blank		Cutting machine, Vise.
2.	Making of internal hexagonal shape at Allen Key Bolt head.		Forging machine, Vise.
3.	Turning on MS blank to provide equal diameter.		Lathe machine, Single point cutting tool, slide callipers, gauge
4.	Facing ends.		Lathe machine, Single point cutting tool, Slide callipers, gauge

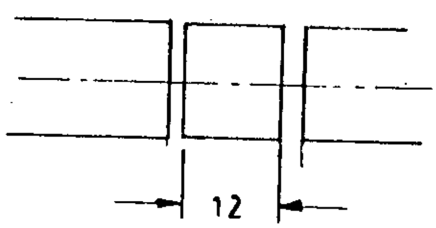
Process Sheet 4.1 (Contd.)

Operation Sheet for Allen Key Bolt Manufacturing.

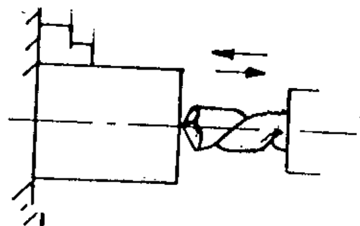
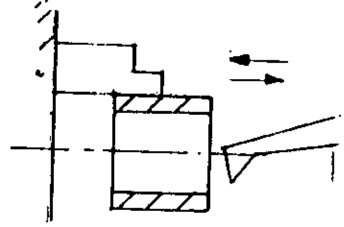
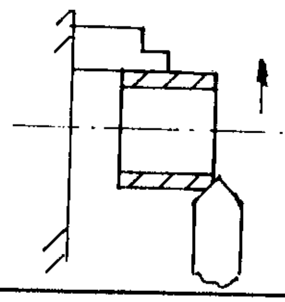
Operation No.	Description	Sketch	Machine Tool
5.	Thread cutting		Lathe machine, thread gauge, single point cutting tool.
6.	Chamfering.		Lathe machine, Slide callipers, Single point cutting tool.

Process Sheet 4.2

Operation Sheet for Nut Manufacturing

Operation No.	Description	Sketch	Machine Tool
1	Cutting of hexagonal MS blank		Cutting machine, Vise.

Process Sheet 4.2 (Contd.)
Operation Sheet for Nut Manufacturing

Oper-ation No.	Description	Sketch	Machine Tool
2.	Drilling to make internal thread		Drilling machine, Visc.
3.	Internal thread cutting		Lathe machine, Slide callipers, thread gauge, Single point cutting tool.
4.	Chamfering		Lathemachine Slide callipers thread gauge Single point cutting tool.

4.3.2 Heat Treatment

Heat treatment is performed on the manufactured and local samples to increase its hardnessand proof stress. For this purpose pack carburizing is performed at first and then quenched for both local and imported samples.

4.3.2.1 Design of Steel Box

For the purpose of pack carburizing a steel box of size 200mmx150mmx120mm is designed and manufactured according to the capacity of furnace of the Department of Industrial and Production Engineering department.

4.3.2.2 Pack Carburizing

Manufactured and local samples are at first taken in the steel box according to its capacity with coal and carburizer. Here carburizer (sodium carbonate and Barium Carbonate) are taken as 20 percent of coal. The box is then covered at the upper side with mud to protect deoxidation at the time of carburizing. Then the box is insert into the furnace. The carburizing temperature is selected at 910^0c and the power supply of furnace is switched on. The specimens are carburized for 2 hours, 3 hours and 5 hours. At every carburizing period, four specimens are taken. Two specimens are manufactured and another two specimens are local. At the end of determined time period, the power supply is switched off and the specimens are allowed to cool to room temperature at the carburizing chamber. After cooling the specimens are taken out of the carburizing chamber.

Another samples of local and manufactured as discussed above are carburized at 910°C. It is then cool about 775^0c at the furnace. The specimen are then removed from chamber and the specimens are quenched immediately in a oil both. The quenched specimens are then tempered quickly at a low temperature of 160^0c to transform the hardened martensite of the case into tempered martensite, relieving the residual stress developed during quenching.

4.4 Testing of the different samples of Nuts and bolts

Microphotography, Microhardness and, tensile testing (proof stress) of different samples of bolts and nuts are tested as follows.

4.4.1 Sample Description

Different types of samples such as local and manufactured are taken for testing. Different aspects such as vickers hardness, Microphotography and tensile testing (proof stress) are performed on these samples. Here local samples are three types, such as raw local sample collected from market, carburized sample and carburized with quenching sample. Manufactured samples are also three types much as samples without heat treatment, pack carburized sample and pack carburized with quenching sample.

4.4.2 Microphotography and Microhardness measurement

Specimen of local and manufactured samples are prepared for testing of microphotography and microhardness as discussed earlier section 4.1.2 and 4.1.3.

4.4.3 Tensile testing

For tensile testing of allen key Bolt and Nut a fixture is designed at first.

4.4.3.1 Design of fixture

The function of fixture is strong enough and to support the workpiece, and to same extent will reflect its size, weight and shape. The fixture must be carefully selected with reference to the workpiece so that neither will be damaged by abrupt contact e.g. damaged by hard steel jaws of tensile testing machine.

Purpose and function of fixture

According to ASTM standard, for the purpose of testing proof stress of allen key Bolt, a fixture shown in the figure 4.1 is designed to provide sufficient thread engagement the nut to the Bolt.

Safety requirement

Safety requirement is essential in the design of fixture. Because when fixture is used for the testing of bolt proof stress, then it may fail and cause an accident. For this reason all function of fixture must be performed with the required firmness of holding, accuracy of positioning and with a high degree of safety for the operator and the equipment.

4.4.3.2 Testing operation

Tensile testing of allen key Bolts and Nut are slightly different from Normal tensile testing. According to ASTM[18]standard the testing procedure is given below:-

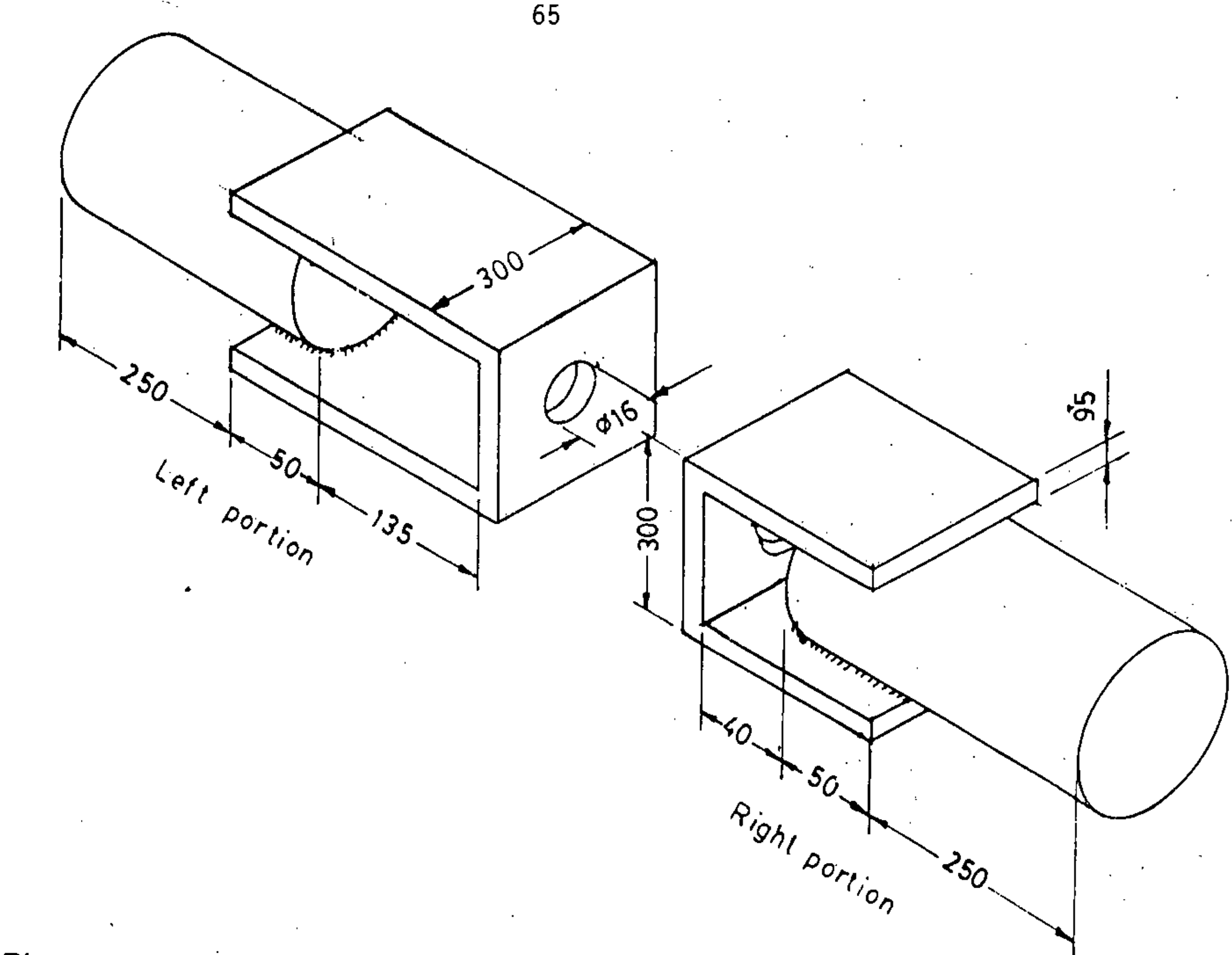


Fig.4.1 a) Fixture for the tensile testing of allen key bolt and nut.

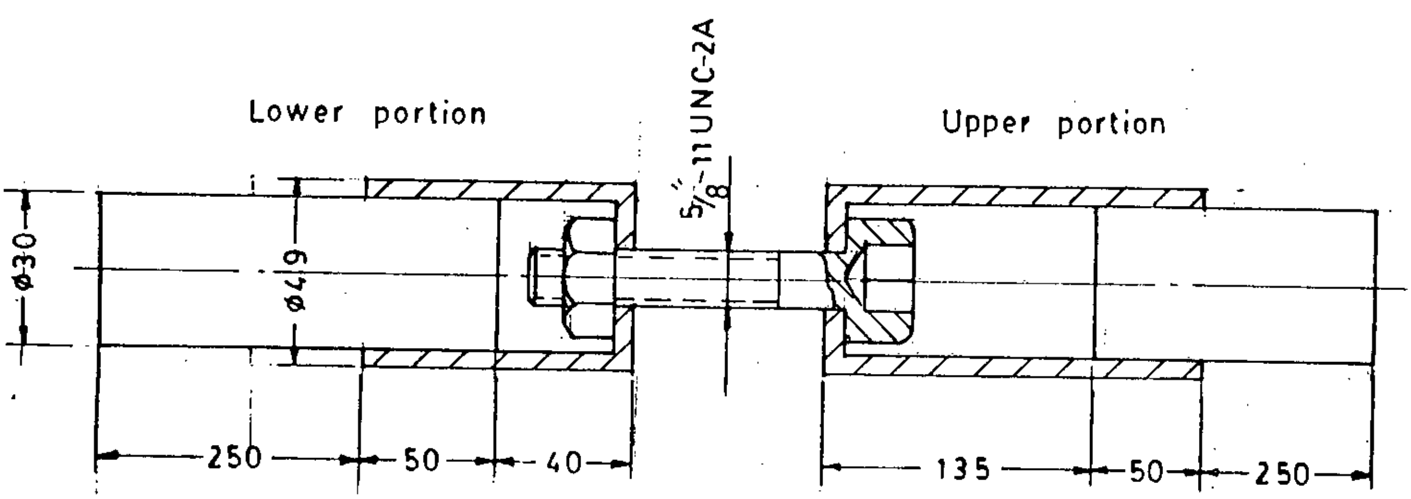


Fig 4.1 (b) Sectional view of the fixture for tensile test.

At first a set of Bolt and Nut is taken for this testing with the fixture. It is then fitted with the tensile testing machine. After fitting load is applied gradually between Bolt and Nut as shown in the figure 4.2. Here it is required togive sufficient thread engagement to develop the full strength of bolt. The nut should be assembled on the bolt leaving six complete bolt threads unengaged between the grips. To meet the requirements of this test. Here it is required to tensile failure on the body or threaded section with no filure converted as requirement. Stress area is converted as requirement. Stress area is calculated from the mean of the root and pitch diameter of class 3 external thread as follows.

$$As = 0.7854(d - (0.9743)/n)^2$$

Where D= Nominal diameter and n= Number of thread per inch.Stress area is also found from the Table 3.2 and Table 3.3

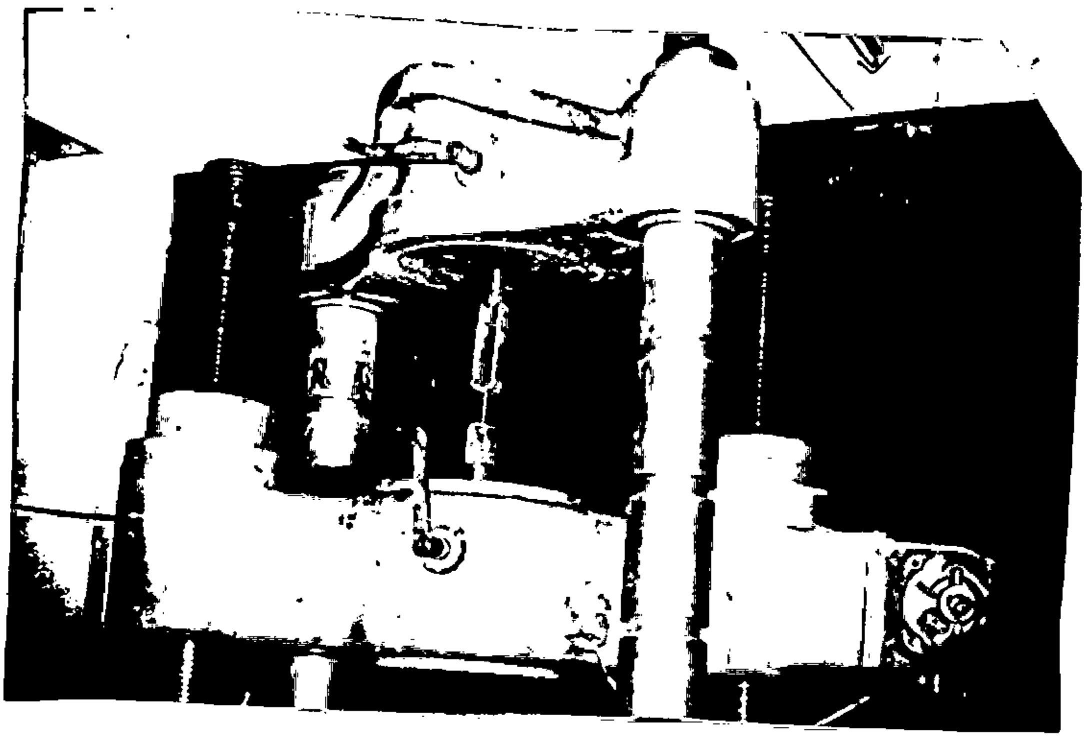


Fig. 4.2 : Experimental Setup of proof stress testing.

CHAPTER - 5

RESULT AND DISCUSSION

5.1 Results of chemical analysis, Microstructure, Hardness test and target Properties

5.1.1 Results of Chemical analysis

Table 5.1

Composition of C, Cr, Mo of foreign and local samples in wt%

Sample No.	C	Cr	Mo
1	0.17	0.99	0.22
2	0.21	1.023	0.24
3	0.18	1.023	0.25
4	0.17	1.213	0.22
5	0.10	-	-
6	0.16	-	-

Samples 1, 2 and 3 shows composition of foreign allen key bolt. These samples contains carbon about 0.2%, but contains Cr and Mo. Sample 4 shows composion of foreign nut. These samples also contains Cr, Mo. From Table 2.3 it is found that both of the steel of allen key Bolt and Nut is AISI no. 4820.

Samples 5 and 6 shows the composition of local allen key Bolt and Nut. These samples do not contain Cr or Mo. These samples are made of low carbon steel.

5.1.2 Results of Microstructure

The microstructure of the polished and etched foreign and local specimens are examined by optical microscopy. Photographs of the structure of each specimen are taken using optical microscope.

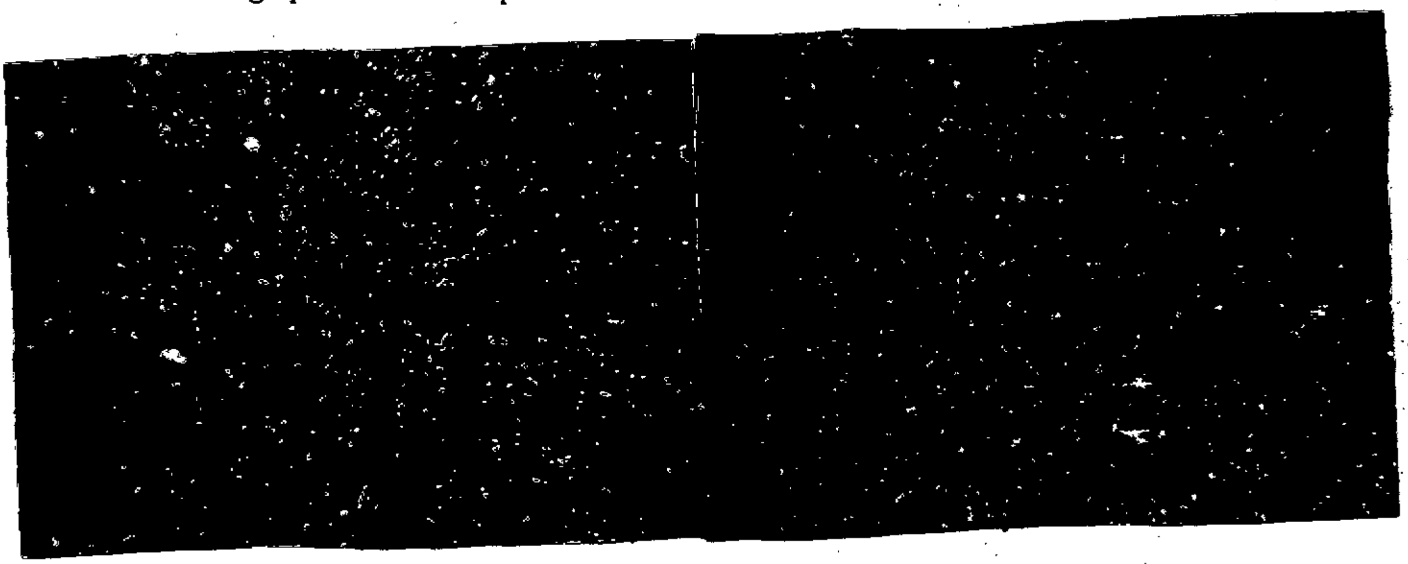


Fig 5.1 Microstructure of foreign allen key (a)Bolt x 200 (b) Nut x 200.

Fig 5.2 Microstructure of foreign allen key Bolt after annealing at 940^{0}C for 2hr x 200 ~~nuts.~~

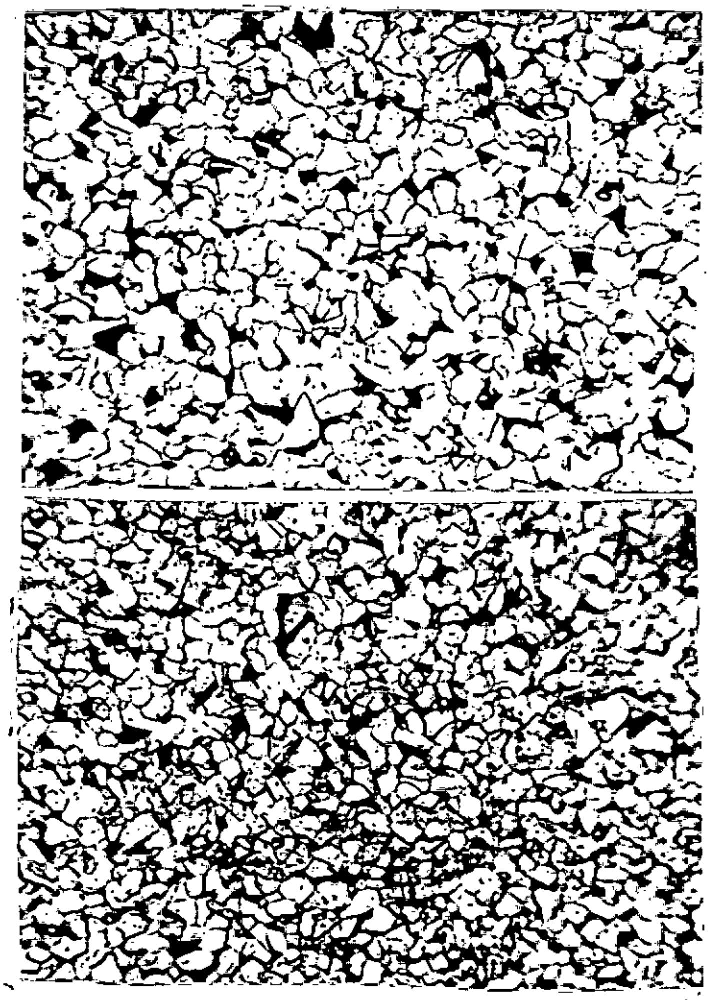


Fig 5.3 Microstructure of local allen key (a) Bolt x 200 (b) Nut x 200

From the above microstructure study (Fig. 5.1) and composition tests it is shows that the foreign samples are made of alloy steel. These compositions are found from the chemical analysis. The microstructure of these samples after annealing at 940^0C for 2 hr time period is shown in the Fig. 5.2.The local samples microstructure shows that it is made by low carbon steel (Fig. 5.3).

5.1.3 Results of Hardness test

After preparation of foreign bolt specimen vickers hardness is tested by a micro hardness testing machine. Hardness is tested at different areas of the specimen at 90^0 section and 45^0 section. At 45^0 section the vickers hardness are as follows.

No of observations	Vickers hardness
1	362.18
2	358.93
3	358.93
4	362.18

Average Vickers hardness is 360.55

At 90^0 section Vickers hardness are as follows.

No of observations	Vickers hardness
1	362.18
2	385.93
3	362.18
4	362.18

Average Vickers hardness is 368.11 Form the above hardness test shows that the average vickers hardness of foreign bolt is 364.44

The hardness of foreign samples are also measured after annealing at 940^0C for 2hr. The hardness is found to be 210.2

The Vickers hardness of foreign Nut is also tested as the same way. The hardness is found to be 340.56.

The hardness values of local sample at 45^0 section are as follows

No of observations	Vickers hardness
1	148.35
2	154.46
3	160.97
4	142.59

Average Vickers hardness is 151.59

The hardness values of local sample at 90^0 section are as follows

No of observations	Vickers hardness
1	127.18
2	137.15
3	160.97
4	148.35

Average Vickers hardness is 143.41.

So, it was found that the average of the Vickers hardness values at 90^0 section and 45^0 section is 147.5. The vickers hardness of local nut is also found to be 137.15. So, these hardness measurement as well as the microstructure test shows that local samples of bolts and nuts are made from low carbon steel.

5.1.3.2 **Manufactured Sample.**

Results of Microhardness test of manufactured samples are shown in the table 5.2

Table 5.2

Microhardness of manufactured Samples (Surface hardness)

Period of Carburizing	Carburized Sample	Carburized with Quenched Sample
0	191.6	191.6
2	231.8	243.8
3	243.8	286.2
5	320.8	473

Above hardness of carburized and carburized with quenched samples are plotted against the carburizing period in figure 5.5 . This figure indicates in the case of carburized with quenched sample the hardness is increases with carburizing period from only carburizing samples. This figure also indicates when carburizing period increases the difference between hardness of these two types of samples increase.

Hardness Profile

When a specimen is carburized, a variation of carbon concentration occurs from the surface to the center of the specimen. The concentration of carbon is high at the surface and decreases towards the core of the specimen. Due to this variation of carbon concentration a hardness gradient exists in a carburized case depending upon carburizing temperature, carburizing time, carburizing element. Results of

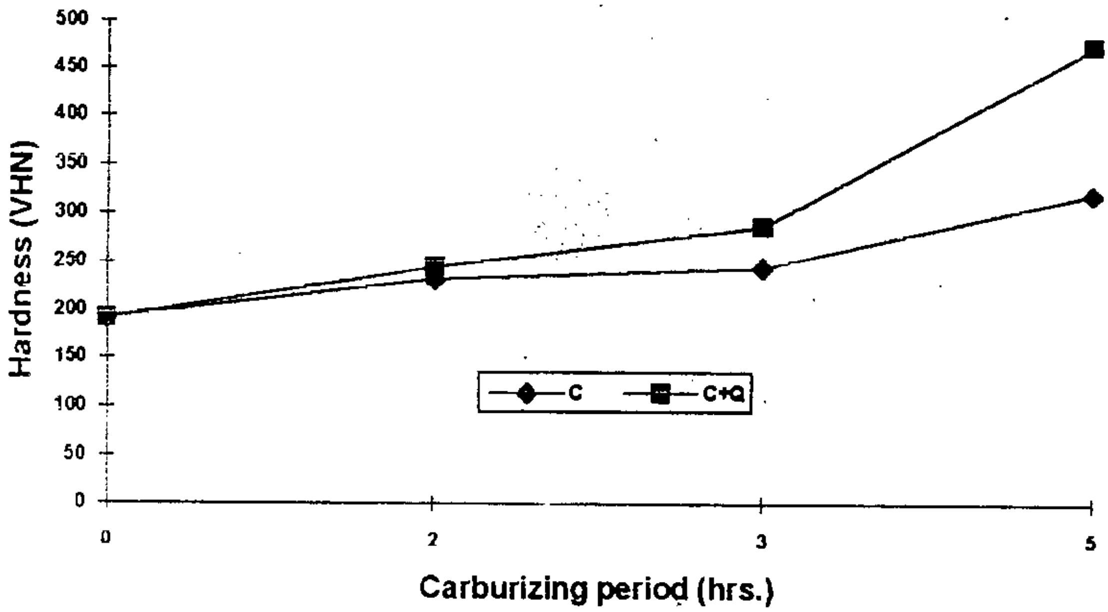


Fig. 5.5 : Hardness (VHN) of manufctured sample at different carburizing period of carburizing and carburizing with quenching sample

Microhardness at horizontal section of axis at different period of carburized with quenched samples are shown in the Table 5.3

The hardness profiles of various samples such as 5hr and 3 hr carburizing with quenched samples are plotted in the figure 5.6 and 5.7. Figure shows that the hardness profiles are parabolic shape. The hardness profile of 5 hr carburizing with quenching samples are more steppers than 3 hr period of carburizing with quenching. It can be found from these figures that change in the slope of the profiles from the carburized layer to the core is very graual. It is observed from the above figure that in general, the case depth increase with the increase of carburizing time.

5.1.4 Target Properties

Target properties of allen key Bolt and Nut are selected from the above test and requirement. These properties are as follows.

i) From the result of hardness test of foreign allen key bolt and Nut (5.1.3) Vickers hardness is selected as 364.44

ii) Proof stress :

Proof stress is selected from the calculation as follows:-

Given Bolt dia D = 5/8 in., Thread UNCand unlubricated.

Required Torque T = 200 ft-lb.

From 3.6, T =CDFi ------------ (1)

Where C = 0.2 for unlubricated bolt .

T = 200 ft-lb

= 200 x 12 in-lb.

Table 5.3

Microhardness from outside to centre of manufactured, carburized and quenched samples.

5hr carburizing and quenching		3 hr carburizing and quenching	
Distance from surface µm	Hardness VHN	Distance from surface µm	Hardness VHN
10	473	20	286
20	362.2	55	270
25	362.2	63	256
43	362.2	83	286.2
62	320.8	133	243.8
80	320.8	193	256.8
100	286.2	258	256.8
110	320.8	323	243.8
140	286.2	398	210.2
180	302.8	458	210.2
220	231.8	523	243.8
260	270	588	191.6
300	231.8	648	243.8
340	270.9	733	175.3
380	286.2	793	161.0
420	286.2	848	231.8
470	320.8	928	256.8
530	286.2		
590	286.2		
600	286.2		
665	320.8		
765	320.8		
965	302.8		

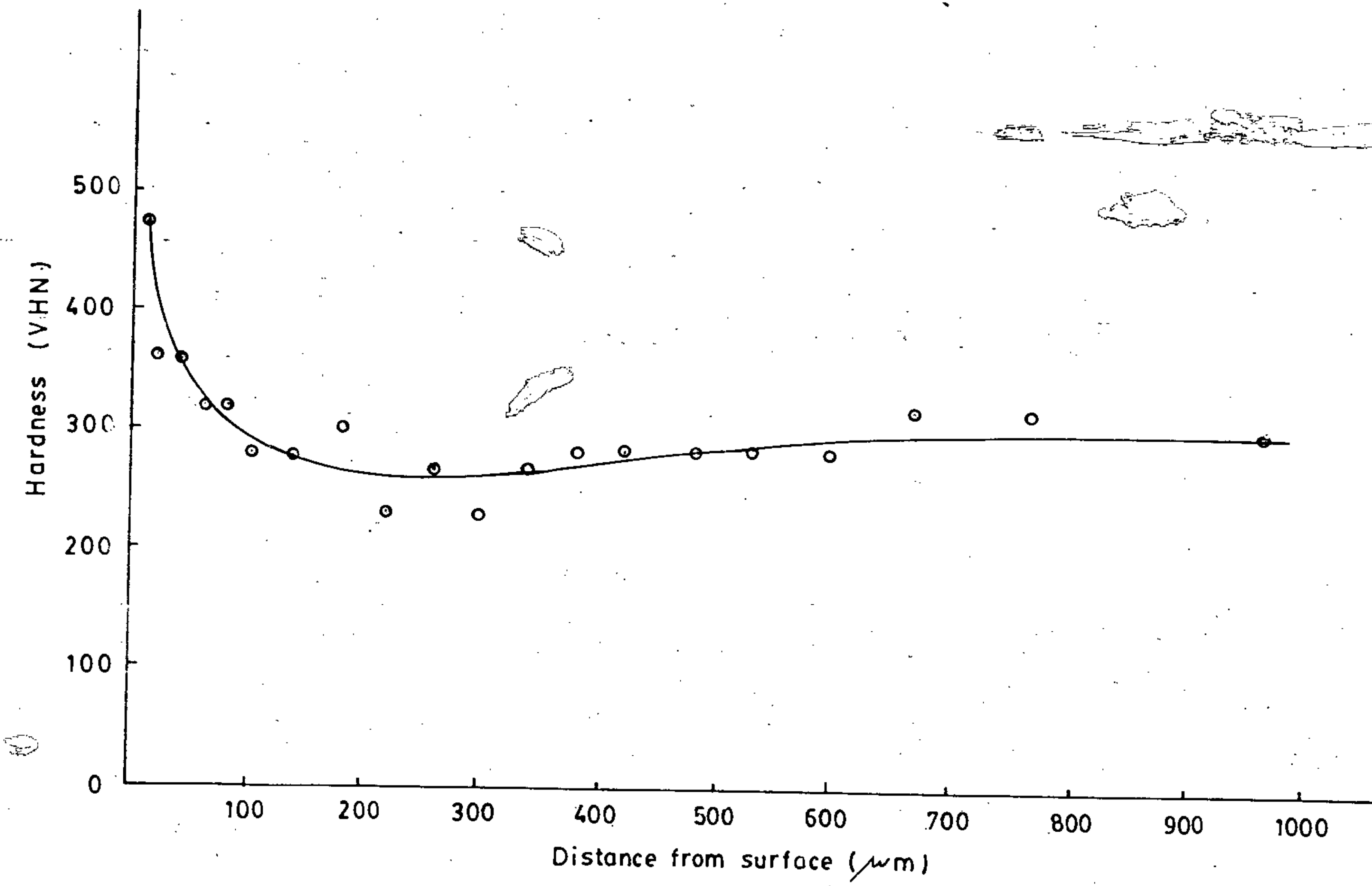


Fig.5.6 Microhardness profile of manufactured sample at 5 hr carburizing with quenching

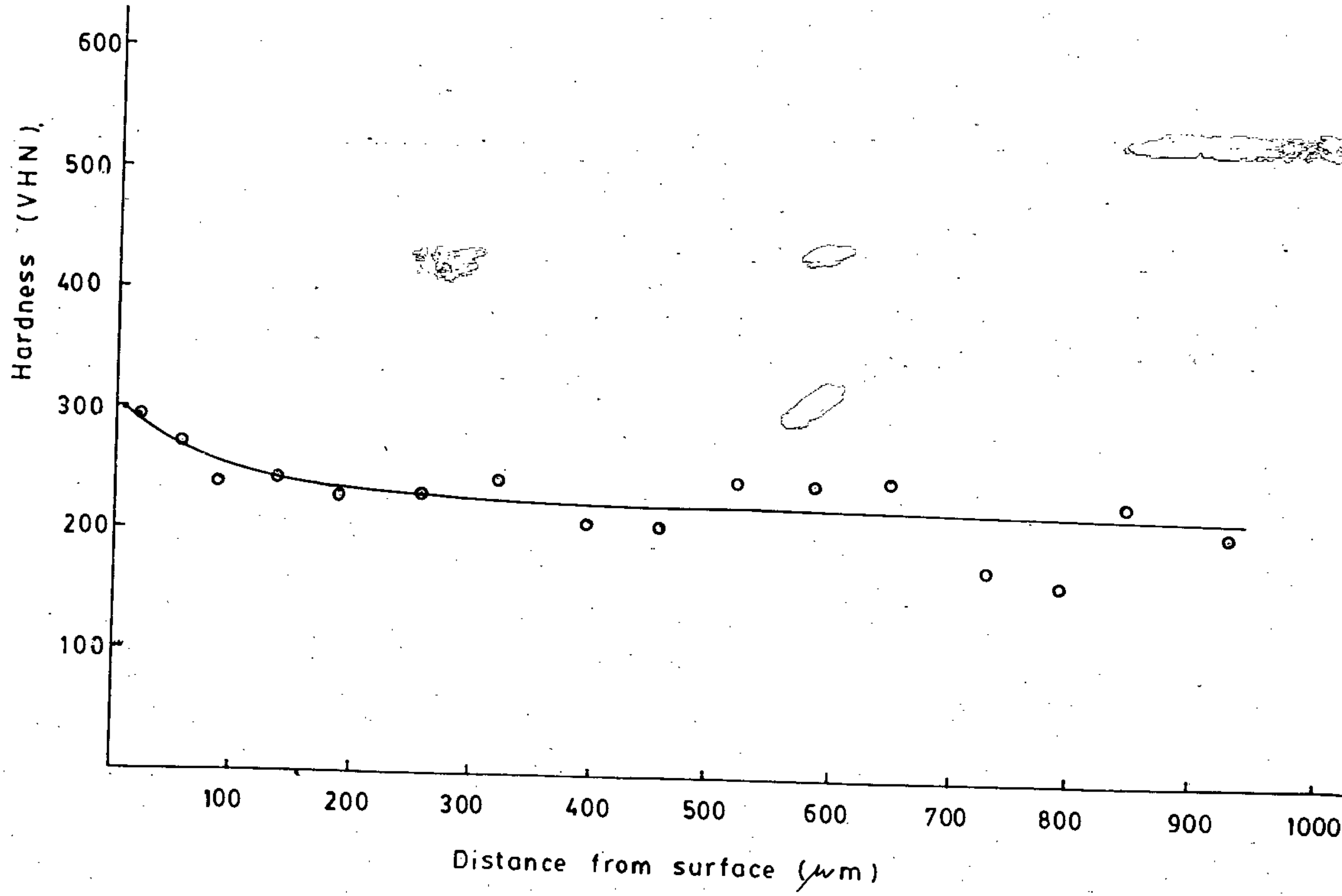


Fig. 5.7 Microhardness profile of manufactured sample at 3 hr carburizing with quenching

From equation 1,

$$200 \times 12 = 0.2 \times 5/8 \times Fi$$

$$\text{or, } Fi = 19200 \text{ lb.}$$

Again from section 4.4.3.2 ,

Stress Stress area

$$As = 0.7854\,(d - (0.9743)/n)^2$$

Where,

D = Nominal diameter = 5/8 in.

n = Number of thread per inch = 11

$$\text{so, } As = 0.7854\,(5/8 - (0.9743)/11)^2$$

$$= 0.226 \text{ in}^2$$

stress area As also found from the Table 3.3 on the basis of bolt dia.

$$\sigma i = Fi / As$$

$$= 19200/0.226$$

$$= 84955 \text{ psi},$$

But from section 3.7,

$$\sigma i = 0.9\sigma p$$

$$\text{or, } \sigma p = \sigma i / 0.9$$

$$= 84955 / 0.9 \text{ psi}$$

$$= 94.39 \text{ ksi.}$$

This properties are possible to attain by using high speed steel. But the production cost will be high. For this reason, available scrap of medium carbon steel can be used with suitable heat treatment.

5.2 Results of thread parameters of local, foreign and manufactured samples.

Thread parameters such as pitch, thread per inch, accuracy of thread maching are observed for local, foreign and manufactured samples. In the local sample, the accuracy of thread machining is rough, actual V shape of the thread is not found and it varies from sample to sample. These are shown in the fig. 5.8.

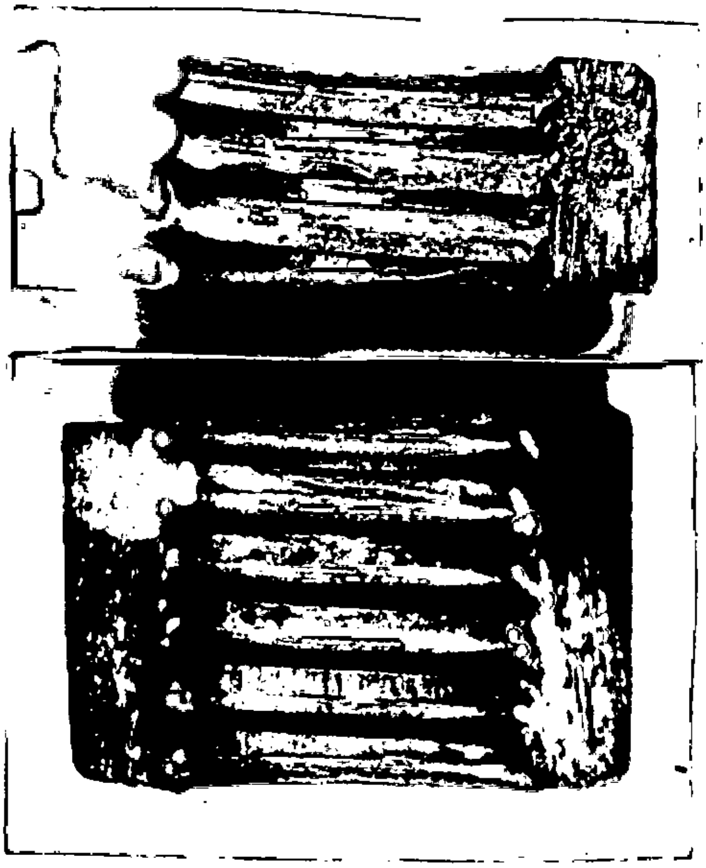


Fig 5.8 Thread machining defect of local samples.

In the foreign sample the accuracy of thread cutting is found good.It has actual V shape of thread , In the manufactured samples thread cutting accuracy is found good. It has also actual V shape of thread.

5.3 Results of Tensile test

Results of tensile tests of different combination of samples are given in the Table 5.4

Table 5.4

Proof stress at different carburizing period for both local and manufactued Samples.

Sample	local(σ p Ksi)	Manufactured(σp Ksi)
No. H. T	49.31	58.92
2 hr C	39.7	59.34
2 hr C+Q	40.12	66.86
3 hr C	38.44	65.14
3 hr C+Q	41.79	93.19
5 hr C	37.61	67.70
5 hr C+Q	42.54	104.89

For local samples a bar chart of σp at different period of carburizing and carbusizing with quenching are plotted (Figure 5.9). The figure shows that in the case of carburized samples σp decreases by larger amount with the increasing of carburizing period as compared to samples with carburizing and quenching. It is described clearly in the figure 5.11. When both carburizing and quenching are performed on the sample there in no significant rise in σp as compared to the same for sample after carburizing alone. Here target property is not attained. Since there is no positive improvement in σp after carburizing and quenching, there can not be any justification of applying these process on the local sample.

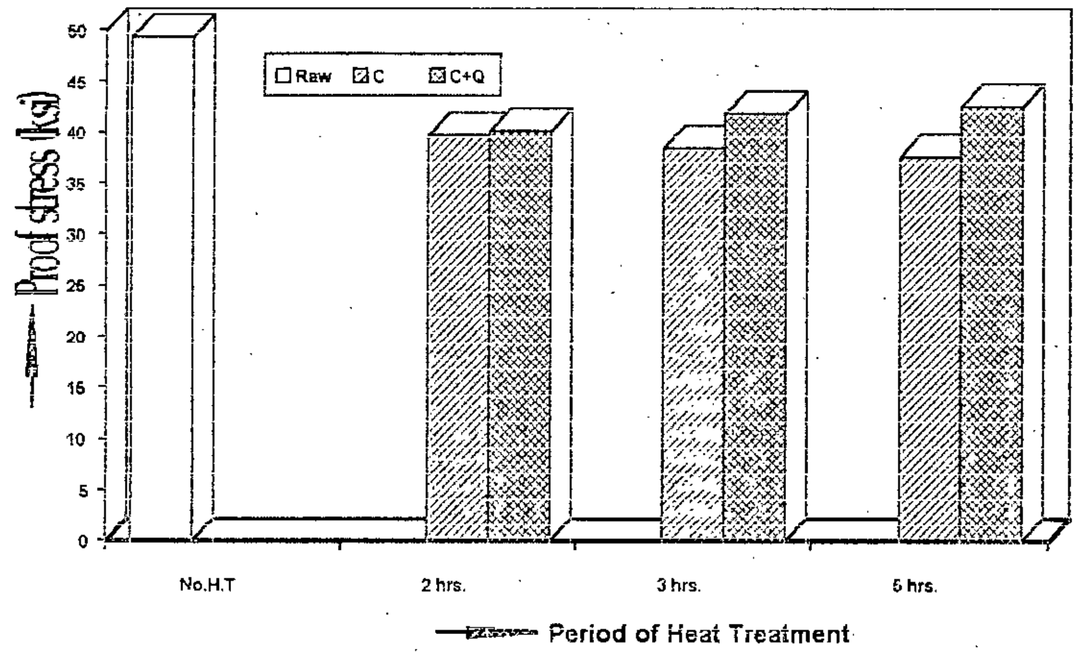


Fig. 5.9 : Proof stress at different carburizing period for local sample

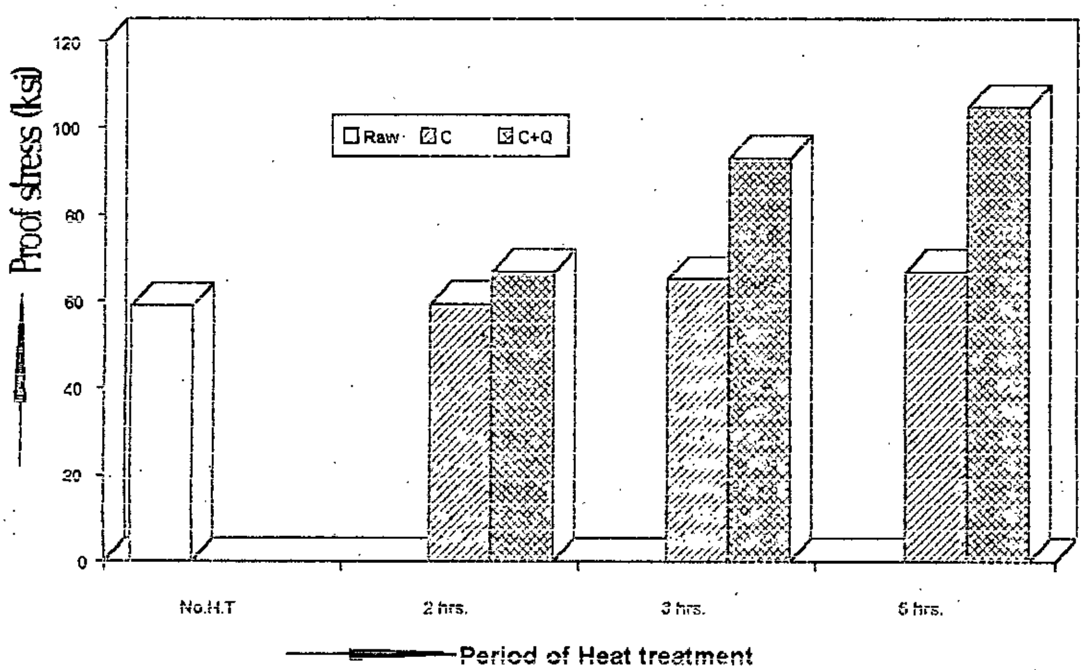


Fig. 5.10 : Proof stress at different carburizing period for manufactured sample

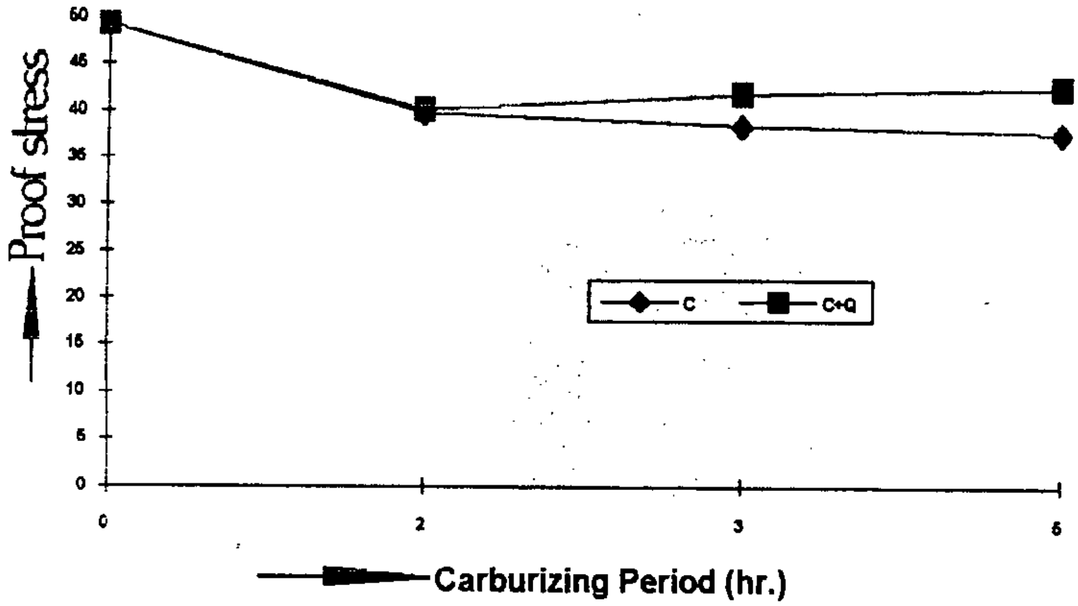


Fig. 5.11 : proof stress vs. carburizing period for local sample

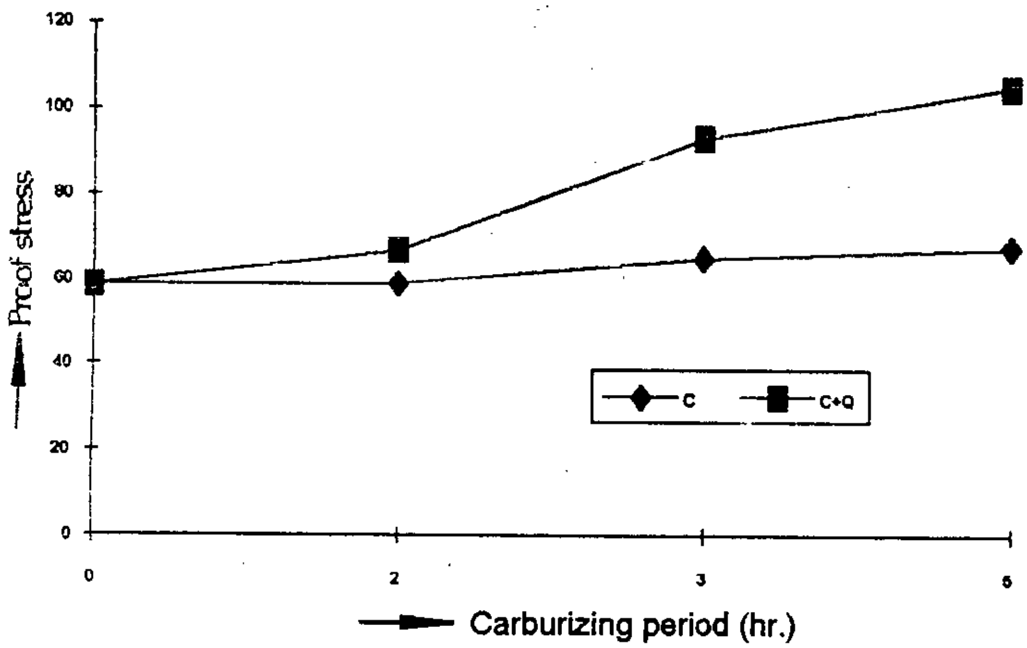


Fig.5.12 : Proof stress vs. carburizing period for manufactured sample

For manufactured samples another bar chart of σp at different carburizing period is also drawn (Figure 5.10). It may be observed from the fig.5.10 that for samples with carburizing and quenching, σp increases more rapidly than in the case of only carburizing sample. It is described more clearly in the fig 5.12. Here it also seen that when increasing the carburizing period, the difference between σp in both the cases increases. Here target property is attained after 3 hr of carburizing and subsequent quenching. Since there is positive improvement in σp after carburizing and quenching, there can be justification of applying these process on the manufactured sample.

CHAPTER -6

Conclusions and Future Recommendations

6.1 Conclusions

From the experimental results and discussion the following conclusions may be drawn:

a) Chemical analysis shows that the material of the imported allen key bolts contains approximately 0.2% C, 1% Cr and 0.24% Mo. The material of the imported nut contains 0.17% C, 1.21% Cr and 0.22% Mo. Whereas the material of the local bolt contains 0.10% C and that of the nut contains 0.16% C. These samples do not contain Cr or Mo.

b) Microstructure and hardness tests reveal that the imported samples of bolt are heat treated up to a hardness of BHN 351. The imported nut is also heat treated. It hardness being BHN 348.The local samples of nut and bolts are not heat treated. The approximate hardness of these samples are found to be BHN142.

c) Test performed to determine the quality of the nut and bolt threads reveal that the quality of threads of local samples of bolt and nut are forwards than those of foreign samples of nuts and bolts.

d) It is found from practical test that the proof stress of the pair of foreign sample of nut and bolts is 128.71 ksi. The proof stress of the pair of local sample of nut and bolt is 49.31 ksi.

e) It is concluded that the causes of lower proof stress of the local samples are inferior quality of the raw material, absence of heat and surface treatment and poor quality of the machine thread.

f) Eight different samples of nuts and bolts are developed on experimental basis with the variation of carburization time and heat treatment conditions.

g) Test shows the quality of the thread of the experimental bolts and nuts are similar to those of the imported samples.

h) Microhardness and Microstructure study of the experimental samples shows that the raw material of the experimental sample is mild steel having hardness of BHN 186. It was also found that the maximum thickness of carbon penetration is in the case of sample which was carburized for 5 hour. But at the same time depth of carbon penetration after 3 hour is also found to be satisfactory.

i) Practical test of the eight experimental samples show that the design proof stress is attained when the samples are carburized for 3 hour or above.

j) It is finally concluded that local manufacture of high strength bolts and nuts ment for press working operations is technologically feasible.

6.2 Future Recommendations

In this project work spare are manufactured from locally available scrap material. The composition of these scrap varies from sample to sample for this reason, it is difficult to control the quality of spares.

If these spares can be manufacture in the mass scale, then actual composition of imported sample material can be imported from abroad and automatic thread cutting machine tools can be used, In that case machining time and production cost could be reduced appreciably.

Although under the present project work manufacture of high strength bolts and nuts with target properties was taken as a case study. Similar case studies could be performed on locally manufacture of other complicated spare parts with target properties.

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