وزارة التعليم العالي والبحث العلمي
الجامعة التقنية الشمالية
المعهد التقني الدور

الحقيبة التعليمية

القسم العلمي: قسم التقنيات الميكانيكية

اسم المقرر: تقنية اجزاء المكائن

المرحلة / المستوى: الثاني

الفصل الدراسي: الاول

السنة الدراسية:2025-2026

الجامعة التقنية الشمالية

معلومات عامة

اسم المقرر:	تقنية اجزاء المكائن					
القسم:	قسم التقنيات الميكانيكية					
الكلية:	المعهد التقني الدور					
المرحلة / المستوى	الثاني					
الفصل الدراسي:	الاول					
عدد الساعات الاسبوعية:	نظري	2	عملي	0		
عدد الوحدات الدراسية:	2					
الرمز:	MTP205					
نوع المادة	نظري	*	عملي		كلهما	
هل يتوفر نظير للمقرر في الاقسام الاخرى	لا يوجد					
اسم المقرر النظير	-					
القسم	-					
رمز المقرر النظير	-					

معلومات تدريسي المادة	
اسم مدرس (مدرسي) المقرر:	نور عبداللطيف عزت
اللقب العلمي:	مدرس مساعد
سنة الحصول على اللقب	2023
الشهادة :	ماجستير
سنة الحصول على الشهادة	2020
عدد سنوات الخبرة (تدريس)	3 سنوات

الوصف العام للمقرر

تقنية اجزاء المكائن مقرر رئيسي لفهم الاجزاء الميكانيكية وتحليلها وتركز على تطوير وتصميم الأجهزة والأنظمة الميكانيكية التي تستخدم في مختلف الصناعات. وتهدف إلى إنشاء حلول هندسية تلبي الاحتياجات الفنية والوظيفية بأقل تكلفة ممكنة وبأعلى كفاءة ممكنة.

الاهداف العامة

- يتعلم الطلاب كيفية تحليل المكونات الميكانيكية المختلفة باستخدام مبادئ الفيزياء والرياضيات، مثل تحميلات القوى والضغوط والعزم.
- يتعلم الطلاب كيفية اختيار المواد المناسبة لكل تطبيق، مع توفير التوازن المثلى بين الموثوقية والتكلفة والأداء.
- يتدرب الطلاب على تصميم الآلات والأجزاء باستخدام برامج الكمبيوتر وأدوات النمذجة الهندسية، مع التركيز على تحقيق الأداء المطلوب والكفاءة.
- يتدرب الطلاب على التعامل مع التحليلات الإجهادية لضمان متانة واستدامة التصاميم، بالإضافة إلى تحسين تصميماتهم الهيكلية.
- يتعلم الطلاب كيفية التفكير الإبداعي والابتكار في تصميم المكائن، وتحسين الأداء والموثوقية وتقليل التكاليف.

الأهداف الخاصة

- تحسين أداء الأجزاء بما يتناسب مع متطلبات التصميم، مثل زيادة الكفاءة والدقة والمتانة والقدرة على تحمل الأحمال.
- تحقيق تكاليف أقل للإنتاج والصيانة، من خلال اختيار المواد المناسبة وتحسين التصميمات لتقليل النفايات وتحسين عمليات التصنيع.
- تطوير تصاميم تتميز بالموثوقية العالية، مما يضمن استمرارية عمل المكائن بكفاءة ودون توقفات غير مخطط لها.
- تطوير تصاميم فعّالة تلبي الاحتياجات الفنية والوظيفية بأقل تكلفة ممكنة وبأعلى كفاءة ممكنة.

أمثلة الأهداف التعليمية .

إكساب المتعلم مهارات الحسابات التصميمية.

تشجيع الطلاب على استخدام التفكير الإبداعي لتطوير حلول تصميمية مبتكرة تلبي الاحتياجات المحددة للتطبيق.

تعلم الطلاب كيفية تقييم تأثير الأحمال الميكانيكية والظروف البيئية على أداء المكائن، وتحسين التصاميم بناءً على هذه الاستجابات.

تدريب الطلاب على قراءة وتحليل وتقييم التصاميم الميكانيكية بناءً على المعايير الهندسية والمواصفات المحددة.

الأهداف السلوكية او نواتج التعلم

- ان يتعلم الطالب التصاميم الميكانيكية وفق المعايير الهندسية والمواصفات المحددة.
- ان يتعلم الطالب استخدام الادوات والبرمجيات الهندسية المختلفة لتصميم وتحليل المكائن.
- ان يميز الطالب المواد الهندسية المختلفة والتي تلبي الاحتياجات الفعلية باقل تكلفة وبأعلى كفاءة ممكنة.
- **أمثلة أهداف تدريسية:**

بعد الانتهاء من المحاضرة سيكون الطالب قادرا على ان:

- كيفية تقييم تأثير الأحمال الميكانيكية والظروف البيئية على أداء المكائن، وتحسين التصاميم

بناءً على هذه الاستجابات.

- قراءة وتحليل وتقييم التصاميم الميكانيكية بناءً على المعايير الهندسية والمواصفات المحددة.
- استخدام الأدوات والبرمجيات الهندسية المختلفة لتصميم وتحليل المكائن، مثل النمذجة الهندسية بالحاسوب وبرامج CAD/CAM .

المتطلبات السابقة

- لا يحتاج الطالب الى أي مواد دراسية سابقة او مهارات معينة.

الأهداف السلوكية او مخرجات التعليم الأساسية		
ت	تفصيل الهدف السلوكي او مخرج التعليم	آلية التقييم
1	. فهم الأساسيات الميكانيكية	• **المحاضرات .** • **الواجبات الفردية والمشاركة .** • **الاختبارات.**
2	تصميم الآلات والمكائن	• **المحاضرات .** • **الواجبات الفردية والمشاركة .** • **الاختبارات.**

3	استخدام البرمجيات الهندسية	• **المحاضرات .** • **الواجبات الفردية والمشاركة .** • **الاختبارات.**
4	التحليل والتقييم	• **الاختبارات** • **المشاريع الفردية والجماعية.**

أساليب التدريس (حدد مجموعة متنوعة من أساليب التدريس لتناسب احتياجات الطلاب ومحتوى المقرر)

الاسلوب او الطريقة	مبررات الاختيار
1. **المحاضرات النظرية والعملية**	تهدف إلى تعليم الطالب كيفية التحليل والتعامل مع المسائل
2. **العصف الذهني**	اسلوب يهدف إلى توليد أفكار جديدة وحلول مبتكرة للمشاكل أو التحديات المطروحة
3. **التفكير الناقد**	تهدف إلى تقييم وتحليل الأفكار والمعلومات بشكل منطقي ومنظم
4. **التواصل اللغوي**	للتأثير على الآخرين وإقناعهم بالآراء أو الفكر الذي يتم تبادله، مما يساهم في بناء القناعات والاتفاقات.
5. **المناقشة والحوار**	تهدف كلاهما إلى تبادل الآراء والأفكار بين الأفراد ومناقشة المواضيع المختلفة

الفصل الاول من المحتوى العلمي							
عنوان الفصل	الوقت						
التوزيع الزمني	النظري	العملي	العنوان الرئيسي	العنوان الفرعي	طريقة التدريس	التقنيات	طرق القياس
الأسبوع الأول	2		Review of Strength of Materials		محاضرة	عرض تقديمي، شرح، أسئلة وأجوبة	عرض الامثلة والمناقشة وملاحظة مستوى الطلبة
الأسبوع الثاني والثالث	2		Riveted Joints	Types of Riveted Joints	محاضرة	عرض تقديمي، شرح، أسئلة وأجوبة	عرض الامثلة والمناقشة وملاحظة مستوى الطلبة
				Design of Riveted Joints	محاضرة	عرض تقديمي، شرح، أسئلة وأجوبة	عرض الامثلة والمناقشة وملاحظة مستوى الطلبة
				Efficiency of Riveted Joints	محاضرة	عرض تقديمي، شرح، أسئلة وأجوبة	عرض الامثلة والمناقشة وملاحظة مستوى الطلبة

اختبار نهاية الفصل:

Q1: Find the efficiency of double riveted lap joint 6 mm plate thickness with 2 cm rivet diameter having a pitch of 6.5 cm assuming the permissible tensile stress in plate is 1200 kg /cm^2, shear stress is 900 kg /cm^2 and crushing stress is 1800 kg /cm^2

Q2: Calculate the strain in a steel rod of square cross-section of side 2 cm when a force of 9800 N is applied and the young's modulus of elasticity is 20.27 × 10^9 N/ m^2.

الفصل الثاني							
عنوان الفصل	الوقت						
التوزيع الزمني	النظري	العملي	العنوان الرئيسي	العنوان الفرعي	طريقة التدريس	التقنيات	طرق القياس
الأسبوع الرابع و الخامس	2		Screwed Joints	Design of Bolts for Fastening	محاضرة	عرض تقديمي، شرح، أسئلة وأجوبة	عرض الامثلة والمناقشة وملاحظة مستوى الطلبة
الأسبوع السادس	2		Screwed Joints	Design of Bolts for Power Transition	محاضرة	عرض تقديمي، شرح، أسئلة وأجوبة	عرض الامثلة والمناقشة وملاحظة مستوى الطلبة

اختبار نهاية الفصل:

Q1: A cylinder head of steam engine is held by 14 bolts , the effective diameter of the cylinder is 35 cm and the steam pressure is 8.5 kg/cm^2 . assuming the tensile stress is not exceed 200 kg/cm^2 . Find the size of the bolt.

Q2: Two shafts connected together by a coupling of 8 bolts ,these bolts putted on a spherical curvature of 10 cm radius . the torque transmitted by the coupling 20000 N.cm , find the size of each bolt assuming that the shear stress 2000 N/cm^2

الفصل الثالث							
عنوان الفصل	الوقت						
التوزيع الزمني	نظري	عملي	العنوان الرئيسي	العنوان الفرعي	طريقة التدريس	التقنيات	طرق القياس
الأسبوع السابع	2		Welded Joints	Types of welding Joints	محاضرة	عرض تقديمي، شرح، أسئلة وأجوبة	عرض الامثلة والمناقشة وملاحظة مستوى الطلبة
الأسبوع الثامن والتاسع	2		Welded Joints	Design of welding Joints	محاضرة	عرض تقديمي، شرح، أسئلة وأجوبة	عرض الامثلة والمناقشة وملاحظة مستوى الطلبة
الأسبوع العاشر والحادي عشر	2		Keyed Joints	Types of Key	محاضرة	عرض تقديمي، شرح، أسئلة وأجوبة	عرض الامثلة والمناقشة وملاحظة مستوى الطلبة
				Design of Sunk Key	محاضرة	عرض تقديمي، شرح، أسئلة وأجوبة	عرض الامثلة والمناقشة وملاحظة مستوى الطلبة

اختبار نهاية الفصل:

Q1: A plate 100 mm wide and 12.5 mm thick is to be welded to another plate by means of parallel fillet welds. The plates are subjected to a load of 50 KN. Find the length of weld so that the maximum stress does not exceed 56 MPs. Consider the joint first under static loading and then under fatigue loading.

Q2: A sunk key of 14 mm width . 20 mm thick and 50 mm length ,is required to transmit torque of 14000 kg.cm from a solid shaft of 4 cm diameter .Calculate if the length of key is enough or not, when the design stresses of the key are for shear 560 kg/cm ^{2} , and crushing stress 1680 kg/cm ^{2} . Also calculate the enough length when the original length of the key cannot sustain the above stress.

الفصل الرابع (من المحتوى العلمي)							
عنوان الفصل	الوقت						
التوزيع الزمني	نظري	عملي	العناوين الرئيسية	العناوين الفرعية	طريقة التدريس	التقنيات	طرق القياس
الأسبوع الثاني عشر	2		Frictional Clutches	Type of Frictional Clutches	محاضرة	عرض تقديمي، شرح، أسئلة وأجوبة	عرض الامثلة والمناقشة وملاحظة مستوى الطلبة
الأسبوع الثالث عشر والرابع عشر	2		Frictional Clutches	Design of Frictional Clutches	محاضرة	عرض تقديمي، شرح، أسئلة وأجوبة	عرض الامثلة والمناقشة وملاحظة مستوى الطلبة

عرض الامثلة والمناقشة وملاحظة مستوى الطلبة	عرض تقديمي، شرح، أسئلة وأجوبة	محاضرة	Design of Springs	Types of Springs		2	الأسبوع الخامس عشر

اختبار نهاية الفصل:

Q1: A helical spring is made from a wire of 6 mm diameter and has a diameter of 70 mm; if the permissible shear stress is 350 MPa and modulus of rigidity 84 KN/mm^2 .find the axial load which spring can carry and the deflection per active turn.

Q2: A single plate clutch, effective on both sides, is required to transmit 25 kW at 3000 r.p.m. Determine the outer and inner diameters of frictional surface if the coefficient of friction is 0.255, ratio of diameters is 1.25 and the maximum pressure is not to exceed 0.1 N/mm2. Also, determine the axial thrust to be provided by springs. Assume the theory of uniform wear.

المحتوى العلمي

strength of material

1.stress :

The internal forces per unit area at any section of the body is known as stress.

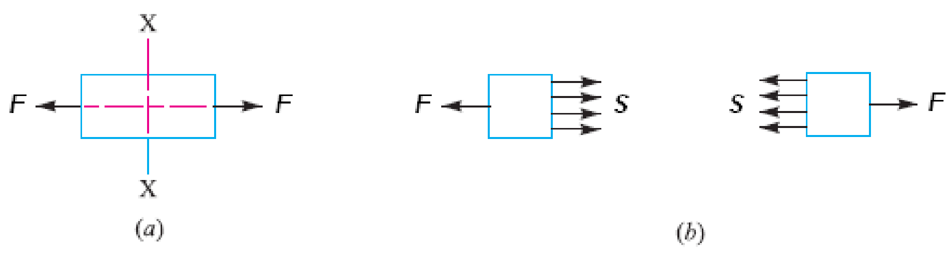
$$S = \frac{F}{A} \qquad (1)$$

Where :

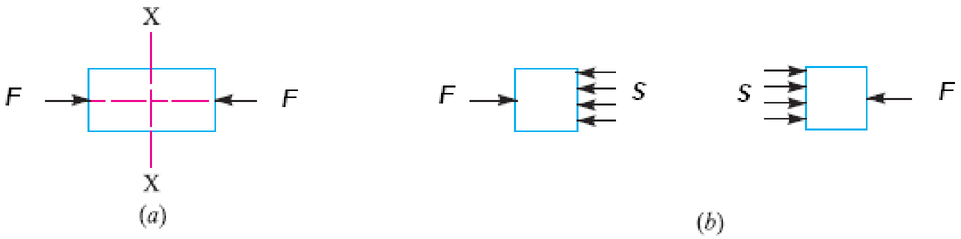
S – stress	N/m^2	or	Kg/cm^2
F – Force	N	or	Kg
A – Area	m^2	or	cm^2

Main types of stress

1. *Tensile stress*



2. Compression stress



Strain: the deformation per unit length

$$\varepsilon = \frac{\delta}{l}$$

where δ – change in length

ε - strain

Modulus of elasticity (E):

Hooks low states that when a material is loaded within elastic limit , the stress is proportional to strain

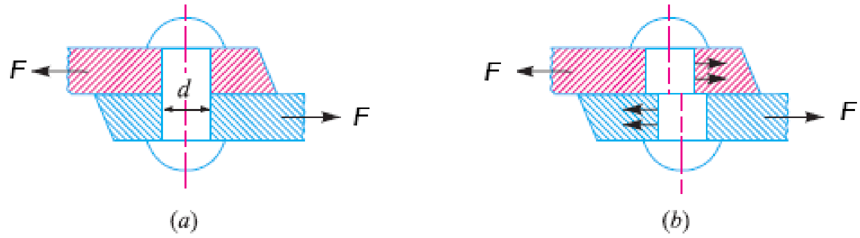
$S \propto \varepsilon$

$S = E \times \varepsilon$

Where E is young modulus of elasticity (constant)

$$E = \frac{S}{\varepsilon} = \frac{F \cdot L}{A \cdot \delta} \qquad N/m^2$$

3. *Shear stress*



$$\tau = \frac{F_s}{A_s}$$

The shear stress is directly proportional to shear strain

$$\tau \propto \phi$$

where

Φ – shear strain

τ *- shear stress*

$$\tau = G \times \phi$$

G – modulus of rigidity

$$\phi = \frac{\tau}{G} \qquad (\text{N})$$

4. *Torsional shear stress*

$$\frac{\tau_s}{r} = \frac{T}{J}$$

$$J = \frac{\pi}{32} \times d^4$$ ***For solid shafts***

$$J = \frac{\pi}{32} \times (D^4 - d^4)$$ *for hollow shafts*

$$\tau_s = \frac{16T}{\pi d^3}$$

For solid shafts

$$\tau_s = \frac{16T\,D}{\pi (D^4 - d^4)}$$

for hollow shaft

τ_s *- max. shear stress*

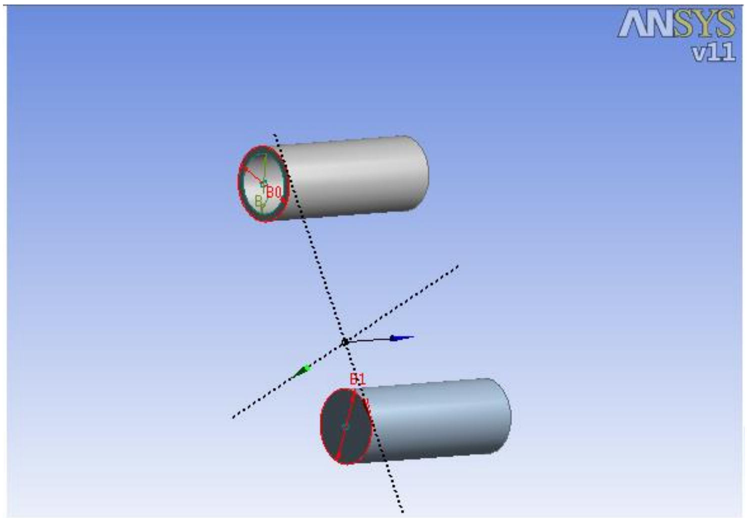
T–torque or twisting moment

r- Radius of the shaft

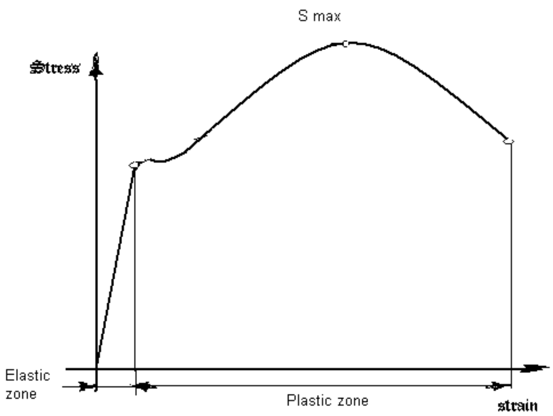
d- Diameter of the shaft

D- outer diameter of shaft

J- polar moment of inertia



Stress –Strain graph



Elastic zone: In this zone whenever the effected load lifted, the body recover to its original shape

Elasticity : it is the property of a material to regain its original shape after deformation when the external forces are removed

Plastic zone : in this zone whenever the effected load lifted, the body cannot recover to its original shape

Plasticity : it is the property of a material which retains the deformation produced under load permenantly..

Yield point : it is about the point which split the elastic and plastic zone.

Max. stress : Maximum stress which can the material sustain

Break stress : the stress which the failure of the material happen , always the maximum stress and the failure stress is the same.

Working stress : when designing machine parts its desirable to keep the stresses lower than the maximum stress at which failure of material takes place . this stress is known as working stress or design stress

Factor of safety :

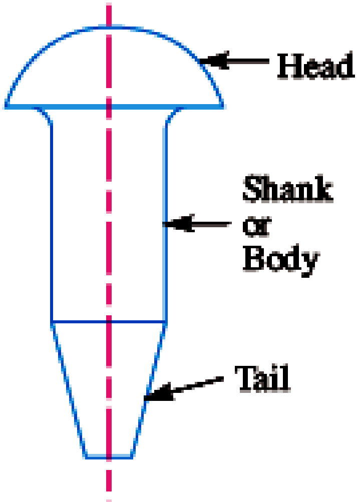
It is defined as the ratio of the maximum stress to the working stress

$$S.F = \frac{\max stress}{working\ stress} = \frac{S_u}{S_w}$$

Riveted joints

A rivet is a short cylindrical bar with a head integral to it. The cylindrical portion of the rivet is called shank or body and lower portion of shank is known as tail.

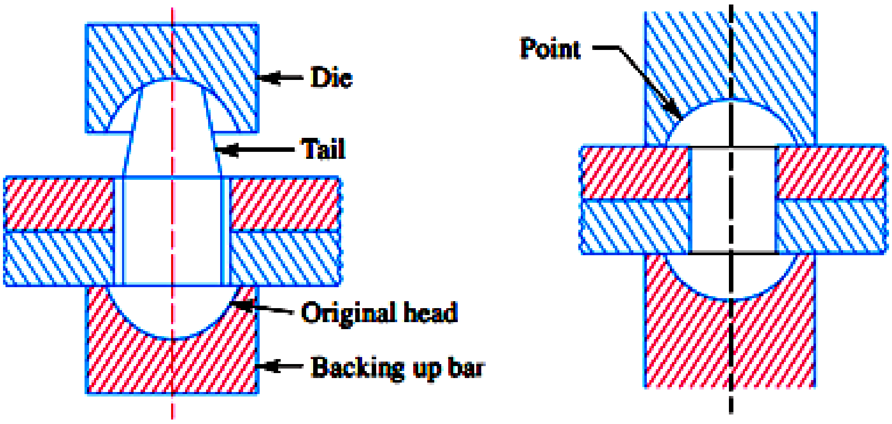
The rivets are used to make permanent fastening between the plates such as in structural work, ship building, bridges, tanks and boiler shells. The rivet joints are widely used for joining light metals.



Method of riveting

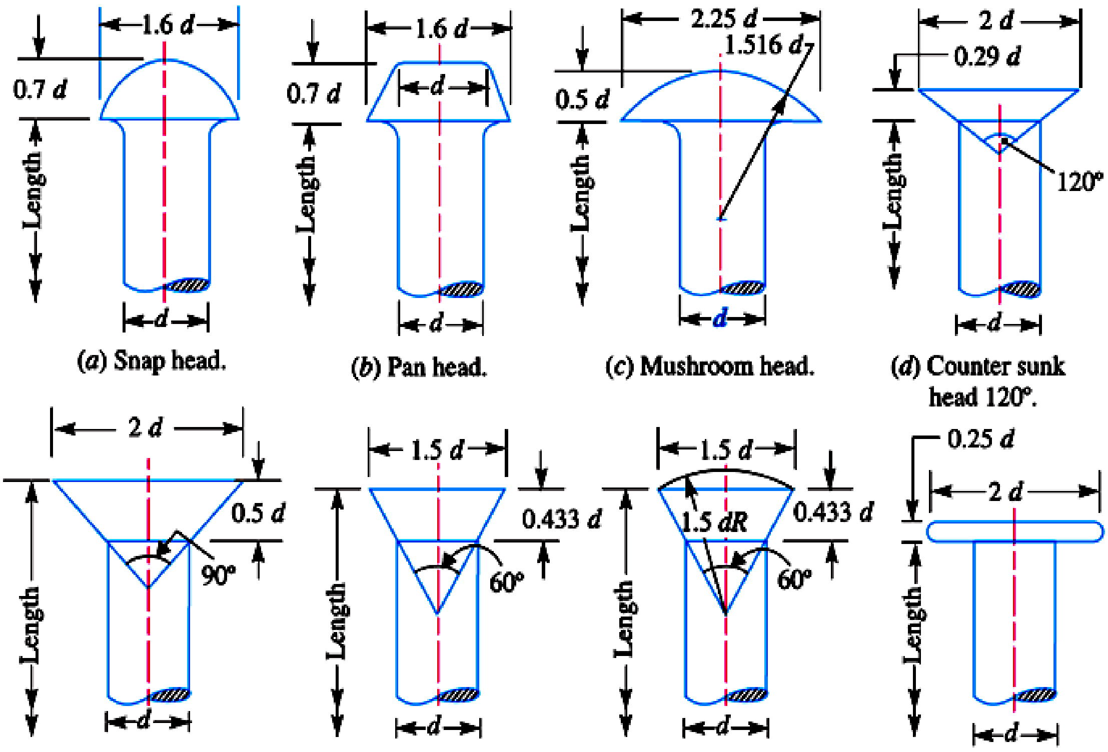
1-drill the plate that would be riveted , the diameter of hole is usually diameter of rivet

2-the red hot rivet is introduced into the plates and the second head is then formed, this may be done by hand or by a riveting machine.



(a) Initial position. (b) Final position.

Types of riveted heads



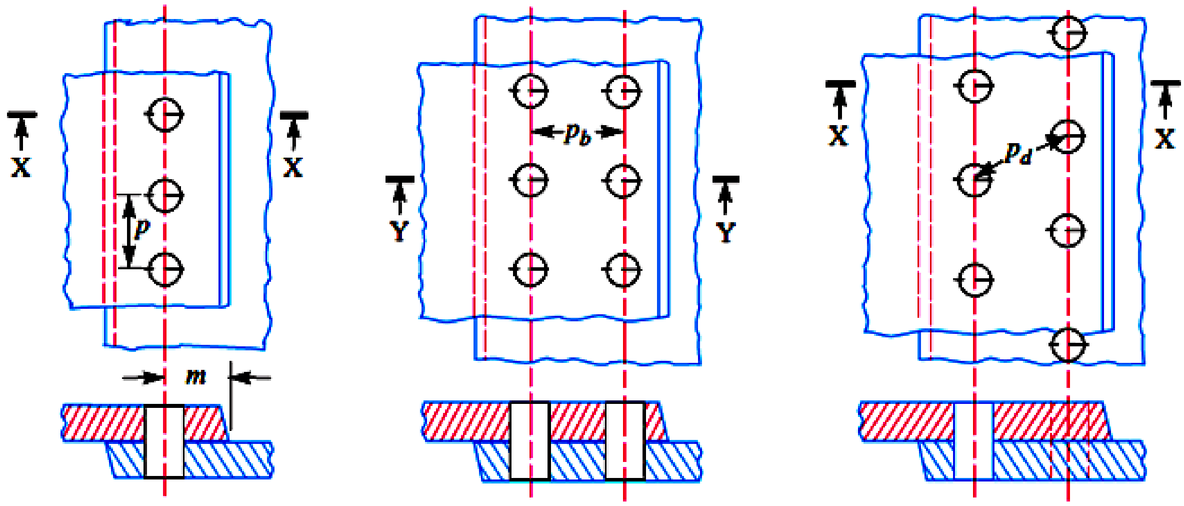
(a) Snap head. (b) Pan head. (c) Mushroom head. (d) Counter sunk head 120°.

(e) Flat counter sunk head 90°. (f) Flat counter sunk head 60°. (g) Round counter sunk head 60°. (h) Flat head.

Types of riveted joints

1- Lap joint

A lap joint is that in which are plate overlaps the other and the two plates are then riveted together



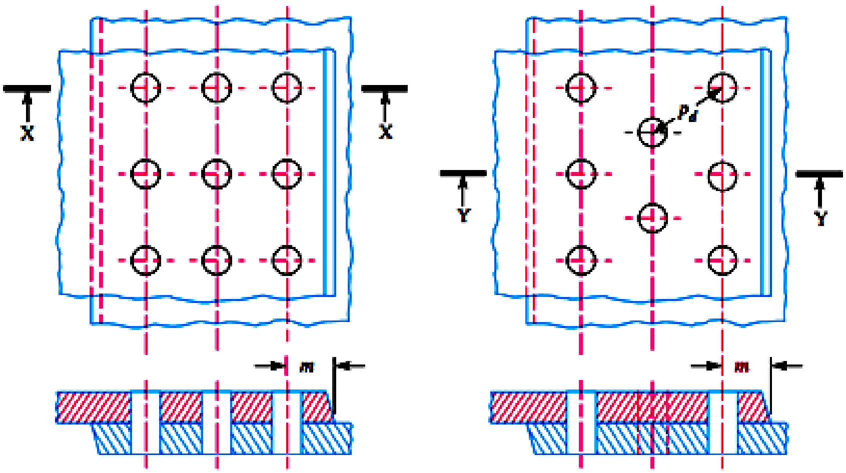
(a) Single riveted lap joint.

(b) Double riveted lap joint (Chain riveting).

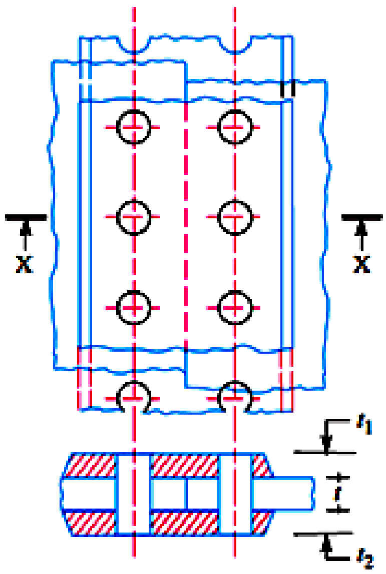
(c) Double riveted lap joint (Zig-zag riveting).

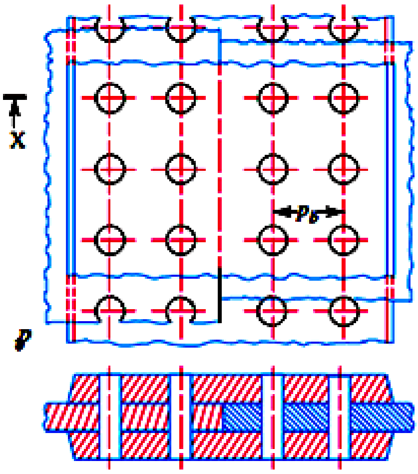
2-Butt joint

A butt joint is that in which the main plates are kept in alignment butting(touching) each other on one side or on both sides of the main plates.

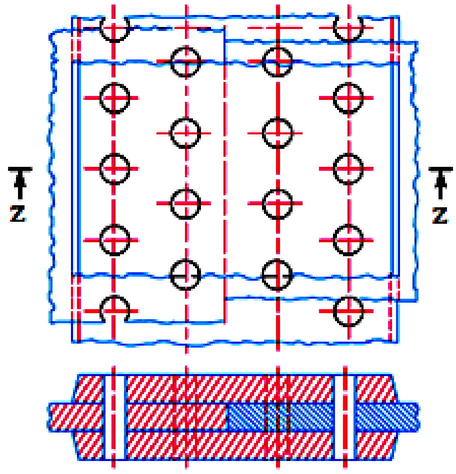


(a) Chain riveting. (b) Zig-zag riveting.

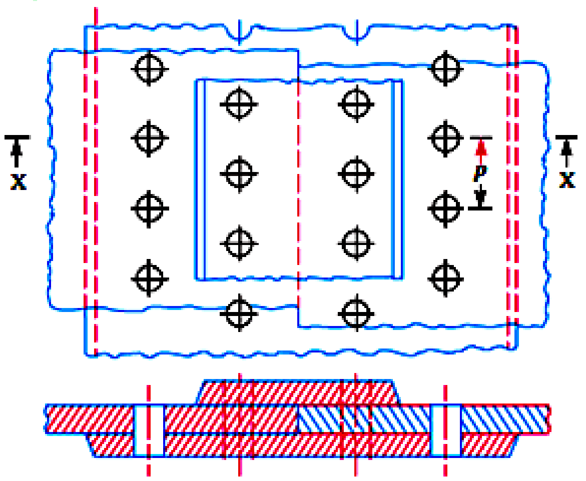




(a) Chain riveting.



(b) Zig-zag riveting.



Technical terms

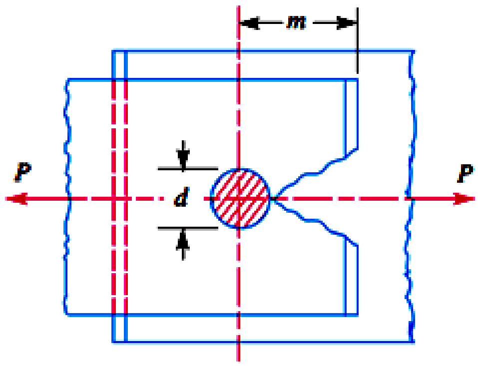
1- Pitch(p): it is the distance from the center of one rivet to the center of the next, measured parallel to the center.

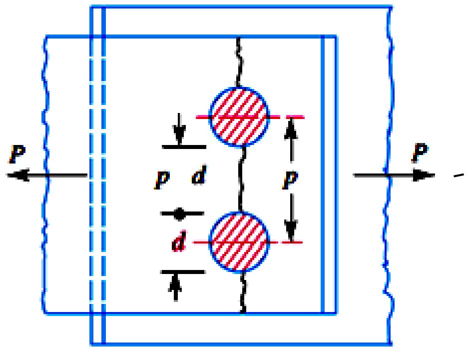
2- Bach pitch(P_b):it is the perpendicular distance between the center lines of the successive rows.

3- Diagonal pitch(P_d):it is the distance between the center of rivet in adjacent rows of zig - zag riveted joints.

4- Margin(M):it is the distance between the center of rivet hole and the nearest edge of the plate.

Failures of riveted joints





1-Tearing of the plate at the edge:

This can be avoided by keeping the margin A (m = 1.5 d)

2-Tearing of the plate across a row of rivets:

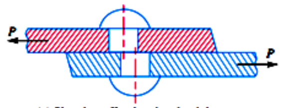
$$A_t = (P - d) \times t$$
$$F_t = A_t \times S_t = (P - d) \times t \times S_t$$

t - thickness of the plate

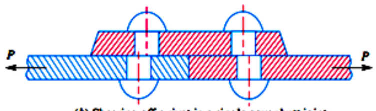
d - diameter of hole

S_t - Tensile stress for the plate material

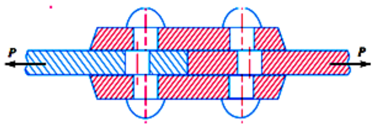
3- Shearing of the rivets:



(a) Shearing off a rivet in a lap joint.



(b) Shearing off a rivet in a single cover butt joint.



$\tau = \dfrac{\textbf{Tangential force}}{\textbf{Resisting area}}$

$$A = \frac{\pi}{4} \times d^2$$

$$\tau = \frac{F}{A} = \frac{F}{\frac{\pi}{4} \times d^2} = \frac{4F}{\pi\ d^2}$$

τ - shear stress on the rivet cross section

d- diameter of the rivet

when the shearing takes place at two cross- sections of the rivet, then the rivets are said to be in (double shear)

$$A = 2 \times \frac{\pi}{4} \times d^2$$

for double rivet cross-sections

$$\tau = \frac{F}{A} = \frac{F}{2 \times \frac{\pi}{4} \times d^2} = \frac{2F}{\pi\ d^2}$$

$$F_s = \frac{\pi}{4} \times d^2 \times n \times \tau$$

Shearing force on the rivet(single shear)

$$F_s = \frac{\pi}{2} \times d^2 \times n \times \tau$$

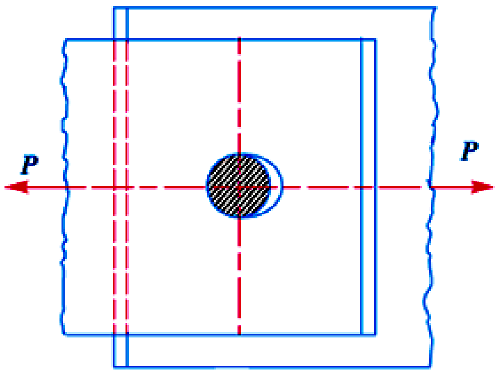
shearing force on the double rivet(double shear)

n- number of rivets per pitch length

note:

All lap joints and single cover butt joints are in single shear , while the butt joints with double cover plates are in double shear.

4- Crushing of the rivet



$$A_c = d \times t$$

$$F_c = d \times t \times n \times S_c$$

d - diameter of the rivet

t - thickness of the plate

n - number of rivets per pitch length

S_c - crushing stress

5-Efficiency of the riveted joints:

The efficiency of the riveted joints is defined as a ratio of strength of riveted joints to the strength of unriveted or (solid) plate.

$$\eta = \frac{\text{least of } Ft, Fs \text{ and } Fc}{\text{strength of unriveted plate}}$$

$$\boldsymbol{\eta} = \frac{\text{least of } Ft, Fs \text{ and } Fc}{P \times t \times St}$$

F_t -Tearing resistance of plate

F_s -Shearing resistance of rivet

F_c -crushing resistance of rivet

P – Pitch

t – thickness of the plate

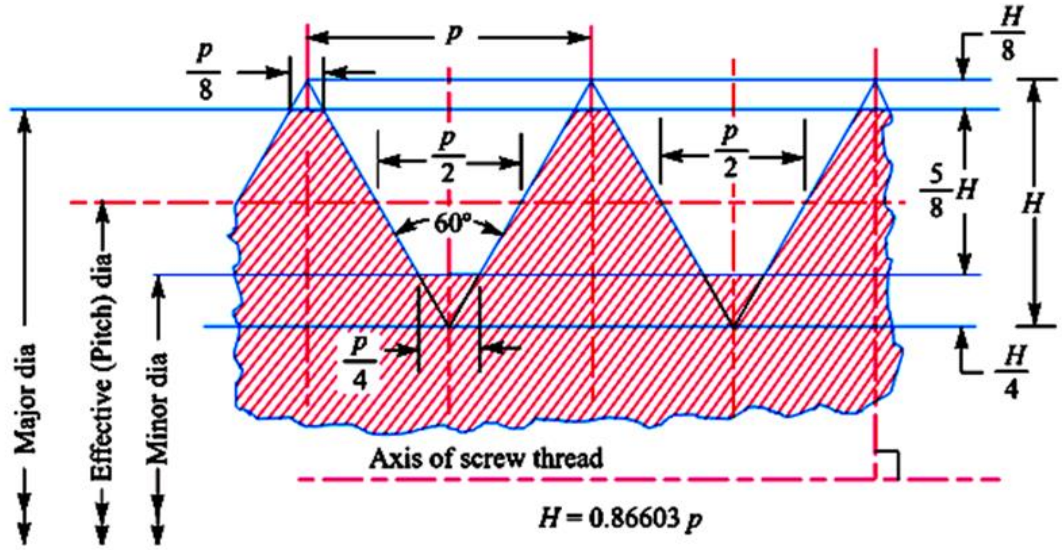
S_t -Tensile strength(stress)of the plate

Screwed joint

Screwed joint are widely used where the machine parts are required to be readily connected or disconnected without damage or for power transmission.

Types of screw thread :

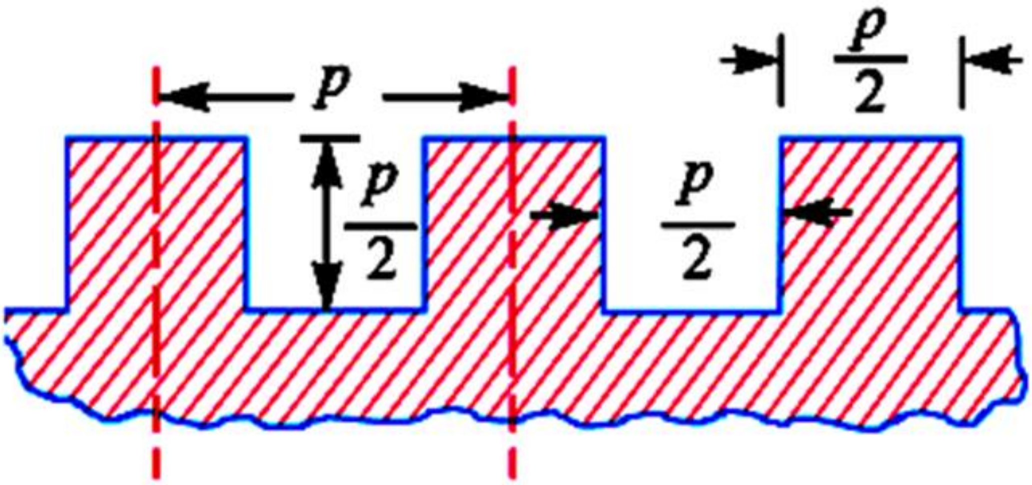
V- thread



P – pitch

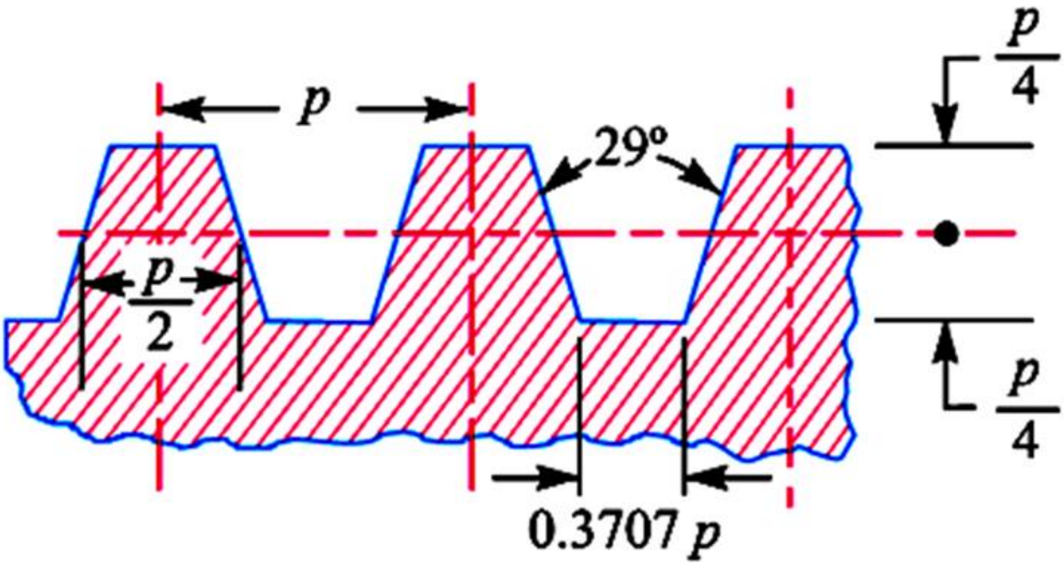
Square thread

Used in feed mechanism tools , values , screw jack .

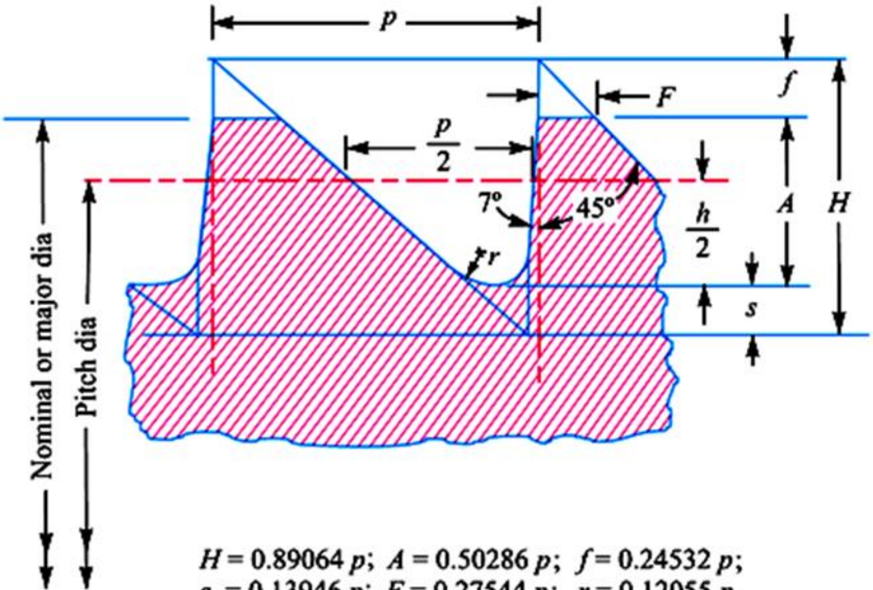


Trapezoidal thread

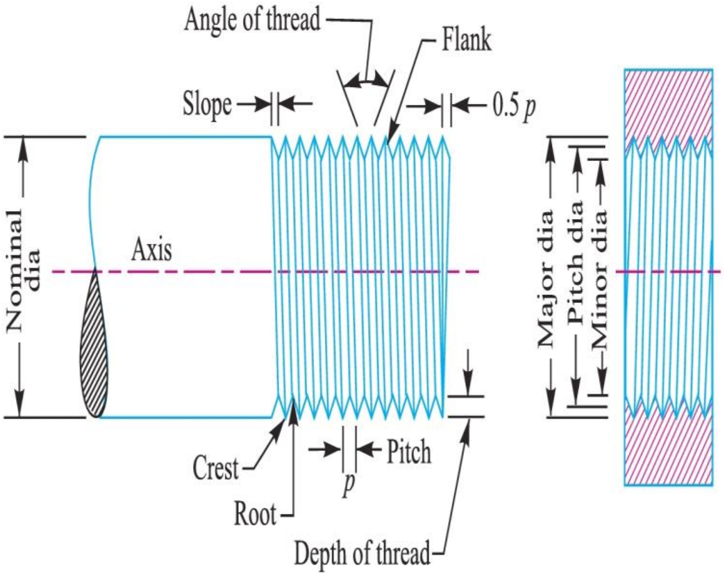
Used on screw cutting lathe , brass valves, and bench vices



Buttress thread



$H = 0.89064\,p$; $A = 0.50286\,p$; $f = 0.24532\,p$;
$s = 0.13946\,p$; $F = 0.27544\,p$; $r = 0.12055\,p$.



Pitch : it’s the distance from a point on one thread to the corresponding point on the next . this is measured in an axial direction between corresponding point in the same axial plane .

Mathematically :

Pitch = 1/(No. of threads per unit length of screw)

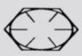
lead : it is the distance between two corresponding points on the same helix. It may also defined as the distance which a screw thread advances axially in one rotation of the nut. Lead is equal to the pitch in case of single start threads , its twice in double start ,trice the pitch in triple start and so on.

Table 11.1. Design dimensions of screw threads, bolts and nuts according to IS : 4218 (Part III) 1976 (Reaffirmed 1996) (Refer Fig. 11.1)

Designation	*Pitch mm*	*Major or nominal diameter Nut and Bolt (d = D) mm*	*Effective or pitch diameter Nut and Bolt (d_p) mm*	*Minor or core diameter (d_c) mm*		*Depth of thread (bolt) mm*	*Stress area mm²*
				Bolt	*Nut*		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Coarse series							
M 0.4	0.1	0.400	0.335	0.277	0.292	0.061	0.074
M 0.6	0.15	0.600	0.503	0.416	0.438	0.092	0.166
M 0.8	0.2	0.800	0.670	0.555	0.584	0.123	0.295
M 1	0.25	1.000	0.838	0.693	0.729	0.153	0.460
M 1.2	0.25	1.200	1.038	0.893	0.929	0.158	0.732
M 1.4	0.3	1.400	1.205	1.032	1.075	0.184	0.983
M 1.6	0.35	1.600	1.373	1.171	1.221	0.215	1.27
M 1.8	0.35	1.800	1.573	1.371	1.421	0.215	1.70
M 2	0.4	2.000	1.740	1.509	1.567	0.245	2.07
M 2.2	0.45	2.200	1.908	1.648	1.713	0.276	2.48
M 2.5	0.45	2.500	2.208	1.948	2.013	0.276	3.39
M 3	0.5	3.000	2.675	2.387	2.459	0.307	5.03
M 3.5	0.6	3.500	3.110	2.764	2.850	0.368	6.78
M 4	0.7	4.000	3.545	3.141	3.242	0.429	8.78
M 4.5	0.75	4.500	4.013	3.580	3.688	0.460	11.3
M 5	0.8	5.000	4.480	4.019	4.134	0.491	14.2
M 6	1	6.000	5.350	4.773	4.918	0.613	20.1
M 7	1	7.000	6.350	5.773	5.918	0.613	28.9
M 8	1.25	8.000	7.188	6.466	6.647	0.767	36.6
M 10	1.5	10.000	9.026	8.160	8.876	0.920	58.3
M 12	1.75	12.000	10.863	9.858	10.106	1.074	84.0
M 14	2	14.000	12.701	11.546	11.835	1.227	115
M 16	2	16.000	14.701	13.546	13.835	1.227	157
M 18	2.5	18.000	16.376	14.933	15.294	1.534	192
M 20	2.5	20.000	18.376	16.933	17.294	1.534	245
M 22	2.5	22.000	20.376	18.933	19.294	1.534	303
M 24	3	24.000	22.051	20.320	20.752	1.840	353
M 27	3	27.000	25.051	23.320	23.752	1.840	459
M 30	3.5	30.000	27.727	25.706	26.211	2.147	561
M 33	3.5	33.000	30.727	28.706	29.211	2.147	694
M 36	4	36.000	33.402	31.093	31.670	2.454	817
M 39	4	39.000	36.402	34.093	34.670	2.454	976
M 42	4.5	42.000	39.077	36.416	37.129	2.760	1104
M 45	4.5	45.000	42.077	39.416	40.129	2.760	1300
M 48	5	48.000	44.752	41.795	42.587	3.067	1465
M 52	5	52.000	48.752	45.795	46.587	3.067	1755
M 56	5.5	56.000	52.428	49.177	50.046	3.067	2022
M 60	5.5	60.000	56.428	53.177	54.046	3.374	2360
Fine series							
M 8 × 1	1	8.000	7.350	6.773	6.918	0.613	39.2
M 10 × 1.25	1.25	10.000	9.188	8.466	8.647	0.767	61.6
M 12 × 1.25	1.25	12.000	11.184	10.466	10.647	0.767	92.1
M 14 × 1.5	1.5	14.000	13.026	12.160	12.376	0.920	125
M 16 × 1.5	1.5	16.000	15.026	14.160	14.376	0.920	167
M 18 × 1.5	1.5	18.000	17.026	16.160	16.376	0.920	216
M 20 × 1.5	1.5	20.000	19.026	18.160	18.376	0.920	272
M 22 × 1.5	1.5	22.000	21.026	20.160	20.376	0.920	333
M 24 × 2	2	24.000	22.701	21.546	21.835	1.227	384
M 27 × 2	2	27.000	25.701	24.546	24.835	1.227	496
M 30 × 2	2	30.000	28.701	27.546	27.835	1.227	621
M 33 × 2	2	33.000	31.701	30.546	30.835	1.227	761
M 36 × 3	3	36.000	34.051	32.319	32.752	1.840	865
M 39 × 3	3	39.000	37.051	35.319	35.752	1.840	1028

Note : In case the table is not available, then the core diameter (d_c) may be taken as 0.84 d, where d is the major diameter.

ASTM AND SAE STANDARDS - SPECIFICATIONS - PROOF LOADS - TENSILE STRENGTHS

Grade Marking	Specification	Material	Bolt and Screw Size (Inches)	Proof Load psi	Tensile Strength min. psi
	SAE-J429 Grade 1	Low or Medium Carbon Steel	1/4 thru 1-1/2	33,000	60,000
	ASTM-A307		1/4 thru 4		60,000
	SAE-J429 Grade-2	Low or Medium Carbon Steel	1/4 thru 3/4 Over 3/4 thru 1-1/2	55,000 33,000	74,000 60,000
	SAE-J429 Grade 5	Medium Carbon Steel Quenched and Tempered	1/4 thru 1 Over 1 thru 1-1/4	85,000 74,000	120,000 105,000
	ASTM-A449		1/4 thru 1 Over 1 thru 1-1/2 Over 1-1/2 thru 3	85,000 74,000 55,000	120,000 105,000 90,000
* 	ASTM-A325 Type 1	Medium Carbon Steel Quenched and Tempered	1/2 thru 1-1/2 Over 1 thru 1-1/2	85,000 74,000	120,000 105,000
	ASTM-A325 Type 3	Weather Resistant Steel Quenched and Tempered	1-1/8 thru 1-1/2 1/2 thru 1	74,000 85,000	105,000 120,000
	ASTM-A354 Grade BB	Low Alloy Steel Quenched and Tempered	1/4 thru 2-1/2 Over 2-1/4 thru 4	80,000 75,000	105,000 100,000
	ASTM-A354 Grade BC	Alloy Steel Quenched and Tempered	1/4 thru 4 Over 2-1/2 thru 4	105,000 95,000	125,000 115,000
	SAE-J429 GRADE 8	Medium Carbon Alloy Steel Quenched and Tempered	1/4 thru 1-1/2	120,000	150,000
	ASTM-A354 Grade BD	Alloy Steel Quenched and Tempered			
	ASTM-A490 Type 1	Alloy Steel Quenched and Tempered	1/2 thru 1-1/2	120,000	150,000

*Radial lines on Type 1 bolts are optional to manufacturer.
Bolt Head markings include manufacturers identity symbols.

Stresses in the threads

Tensile stress due to stretching of bolts

$$S_t = \frac{Ft}{A} \Rightarrow \frac{Ft}{\frac{\pi}{4} d_i^2} \qquad \Rightarrow d_i = \sqrt{\frac{4Ft}{\pi \times S_t}}$$

S_t- tensile stress

Ft- tensile force

d_i*-minor diameter or core diameter*

Torsional shear stress

It caused by the friction resistance of the threads during tightening.

$$\frac{\tau_s}{r} = \frac{T}{J}$$

$$J = \frac{\pi}{32} \times d^4$$

$$\tau_s = \frac{16\,T}{\pi\, d_i^3}$$

τ_s -Torsional shear stress

T – Torque

Shear stress across the thread

$$\tau = \frac{F_s}{\pi \ d_i b \ n}$$ for screw

$$\tau = \frac{F_s}{\pi \ d_o b \ n}$$ For nut

b- width of the thread section of root
n- number of the threads in engagement

Crushing stress on thread

$$S_c = \frac{4F_c}{\pi(d_o^2 - d_i^2)n}$$

$d_i = 0.84 \ d_o$

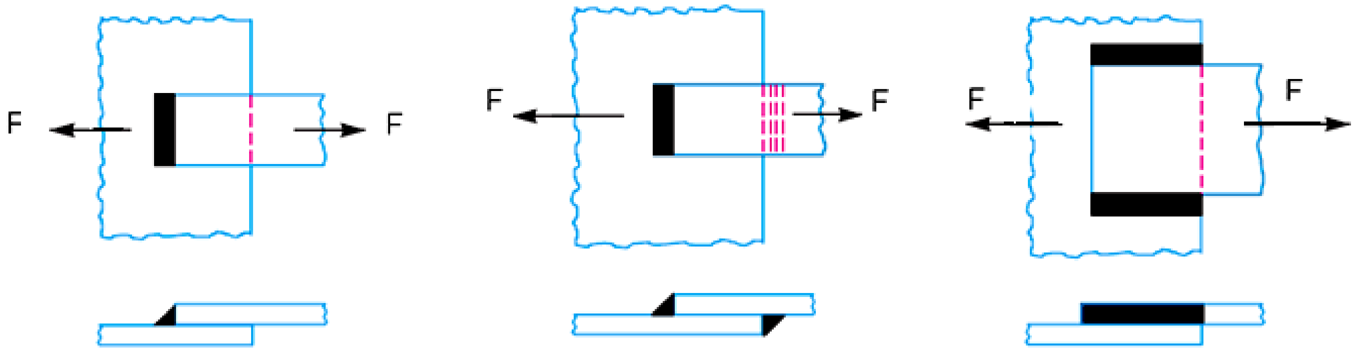
d_o-outside diameter

Welding

A welded joint is a permanent joint which is obtained by the fusion of the edges of the two parts to be joined together, with or without the application of pressure and a filler material. The heat required for the fusion of the material may be obtained by burning of gas (in case of gas welding) or by an electric arc (in case of electric arc welding) . the later method is extensively used because of greater speed of welding.

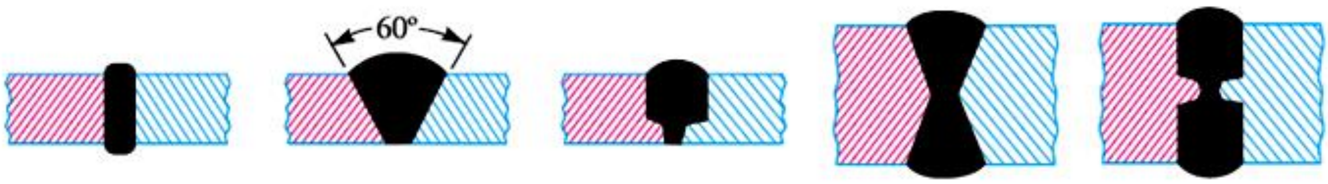
Types of welding joints

1.lap joint or fillet joint



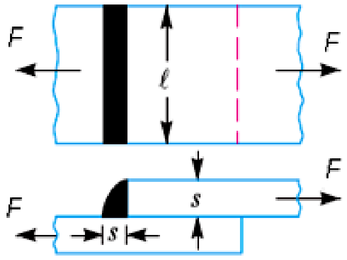
(*a*) Single transverse. (*b*) Double transverse. (*c*) Parallel fillet.

2.Butt joint

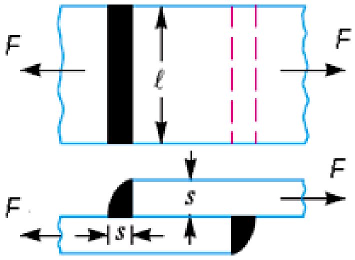


(*a*) Square butt joint. (*b*) Single *V*-butt joint. (*c*) Single *U*-butt joint. (*d*) Double *V*-butt joint. (*e*) Double *U*-butt joint.

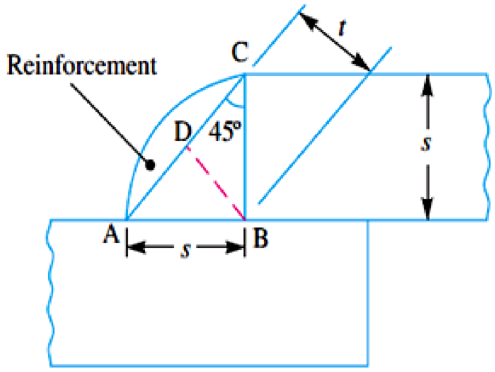
Strength of transverse fillet welded joints



(*a*) Single transverse fillet weld.



(*b*) Double transverse fillet weld.



Let t = Throat thickness (*BD*),

s = Leg or size of weld,

= Thickness of plate, and

l = Length of weld,

$t = s \times \sin 45° = 0.707\, s$

∴ Minimum area of the weld or throat area,

A = Throat thickness × Length of weld $= t \times l = 0.707\, s \times l$

Tensile force of the joint for single fillet

$$F_t = A \times S_t$$

$$F_t = 0.707 s \times l \times S_t$$

Where

S_t - allowable tensile stress for weld metal

Tensile force of the joint for double fillet

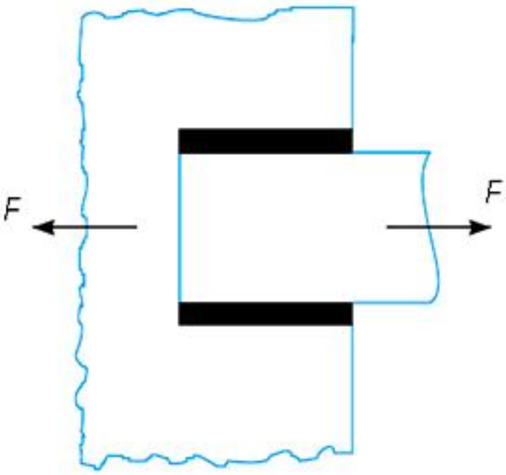
$$F_t = 2 \times 0.707\ s \times l \times S_t$$

$$F_t = 1.414\ s \times l \times S_t$$

Strength of parallel fillet welded joints

F = Throat area × Allowable shear stress = $0.707\ s \times l \times \tau$

$$F = 2 \times 0.707 \times s \times l \times \tau \; = \; 1.414\ s \times l \times \tau$$

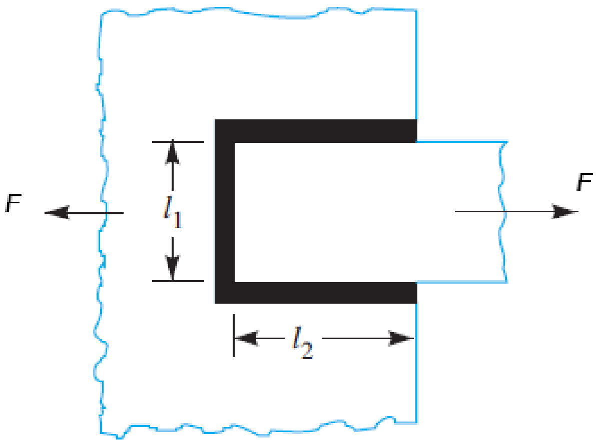


(*a*) Double parallel fillet weld.

Notes: 1. If there is a combination of single transverse and double parallel fillet welds. Then the strength of the joint is given by the sum of strengths of single transverse and double parallel fillet welds.

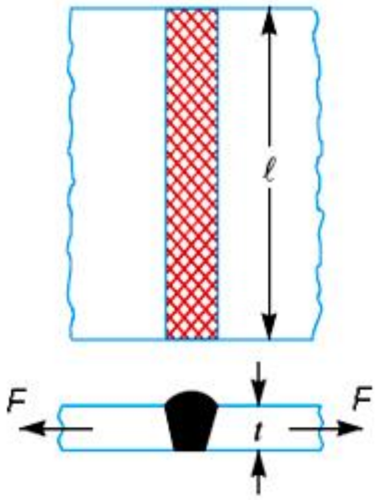
Mathematically, $F = 0.707 s \times l_1 \times \text{St} + 1.414\ s \times l_2 \times \tau$

in order to allow for starting and stopping of the bead , 12.5 mm should be added to the length of each weld.

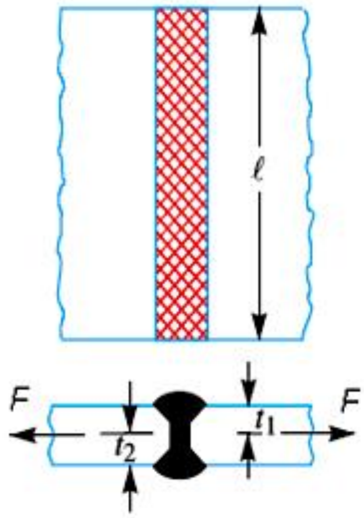


(*b*) Combination of transverse and parallel fillet weld.

Strength of butt joints



(*a*) Single *V*-butt joint.



(*b*) Double *V*-butt joint.

In case of butt joint, the length of leg or size of weld is equal to the throat thickness which is equal to thickness of plates.

∴ Tensile strength of the butt joint (single-*V* or square butt joint),

$F = t \times l \times St$ $\qquad l$ = Length of weld. It is generally equal to the width of plate.

Tensile strength for double- V or square butt joint

$F = (t_1 + t_2)\ l \times St$ $\qquad t_1$ = Throat thickness at the top, and

t_2 = Throat thickness at the bottom.

Stress concentration factor

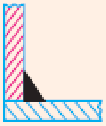
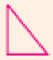
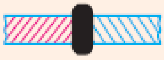
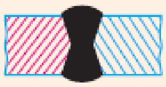
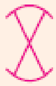
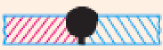
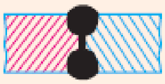
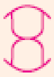
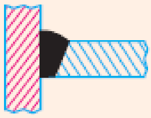
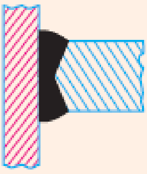
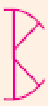
When the parts of welded joint are subjected to fatigue loading(dynamic loading) the S.C.F as given below should be taken into account.

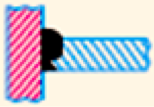
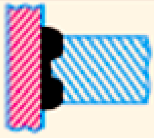
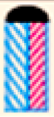
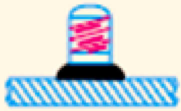
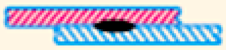
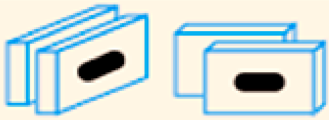
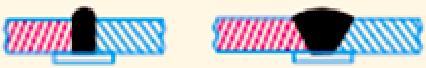
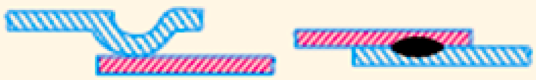
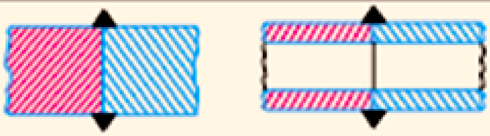
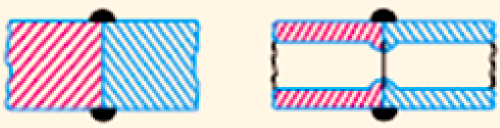
Type of joint	Stress concentration factor
1. Reinforced butt welds	1.2
2. Toe of transverse fillet welds	1.5
3. End of parallel fillet weld	2.7
4. T-butt joint with sharp corner	2.0

$$S_t = \frac{S_t}{S.C.F} \qquad , \tau = \frac{\tau}{S.C.F}$$

Note: for static loading and any type of joint , S.C.F = 1

Basic weld symbols

S. No.	Form of weld	Sectional representation	Symbol
1.	Fillet		
2.	Square butt		
3.	Single-*V* butt		
4.	Double-*V* butt		
5.	Single-*U* butt		
6.	Double-*U* butt		
7.	Single bevel butt		
8.	Double bevel butt		

S. No.	Form of weld	Sectional representation	Symbol
9.	Single-J butt		
10.	Double-J butt		
11.	Bead (edge or seal)		
12.	Stud		⊥
13.	Sealing run		○
14.	Spot		
15.	Seam		
16.	Mashed seam	 Before After	
17.	Plug		
18.	Backing strip		=
19.	Stitch		
20.	Projection	 Before After	△
21.	Flash	 Rod or bar Tube	
22.	Butt resistance or pressure (upset)	 Rod or bar Tube	|

keys

key : it is a piece of metal has different forms used to prevent relative motion between a shaft and the connected member (hub) through which torque is being transmitted .

Types of keys :

1.sunk keys

2.saddle keys

3.tangent keys

4.round keys

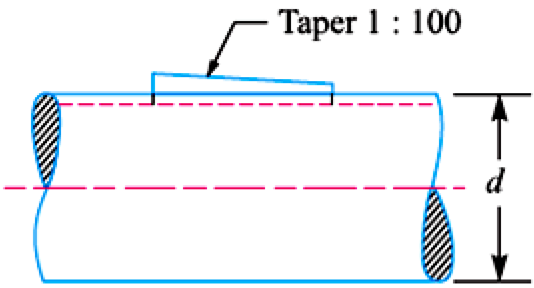
5.splines

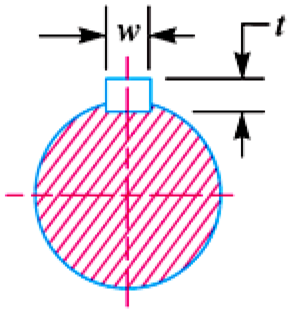
Sunk keys

The sunk keys are provided half in the keyway of the shaft and half in the keyway of the hub.

The sunk keys are the following types:

a. Rectangular sunk keys:





$$w = \frac{d}{4}$$

$$t = \frac{2w}{3} = \frac{2 \times \frac{d}{4}}{3} = \frac{d}{6}$$

w – width of key

t – thickness of key

d – diameter of the shaft

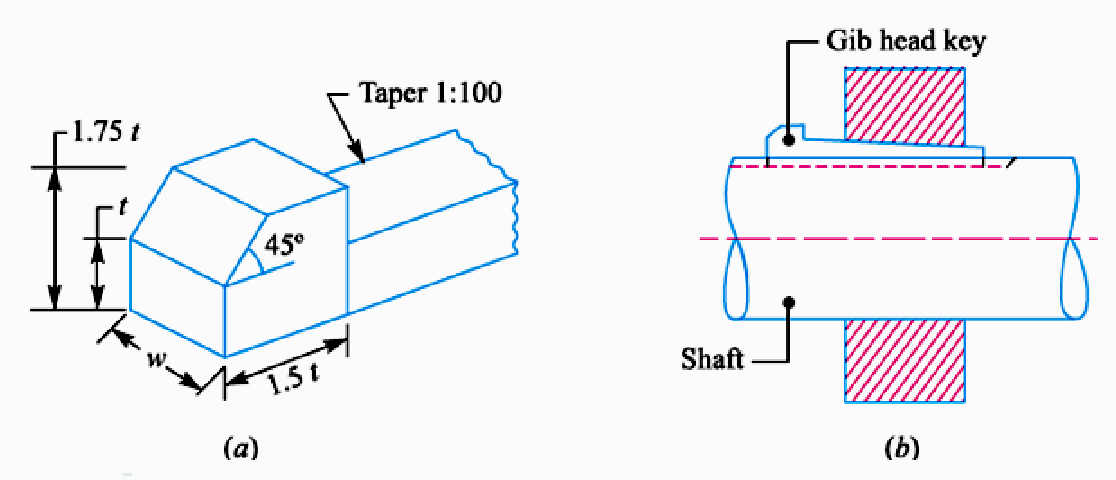
the key has taper 1 in 100 on the top side only

b. square sunk key

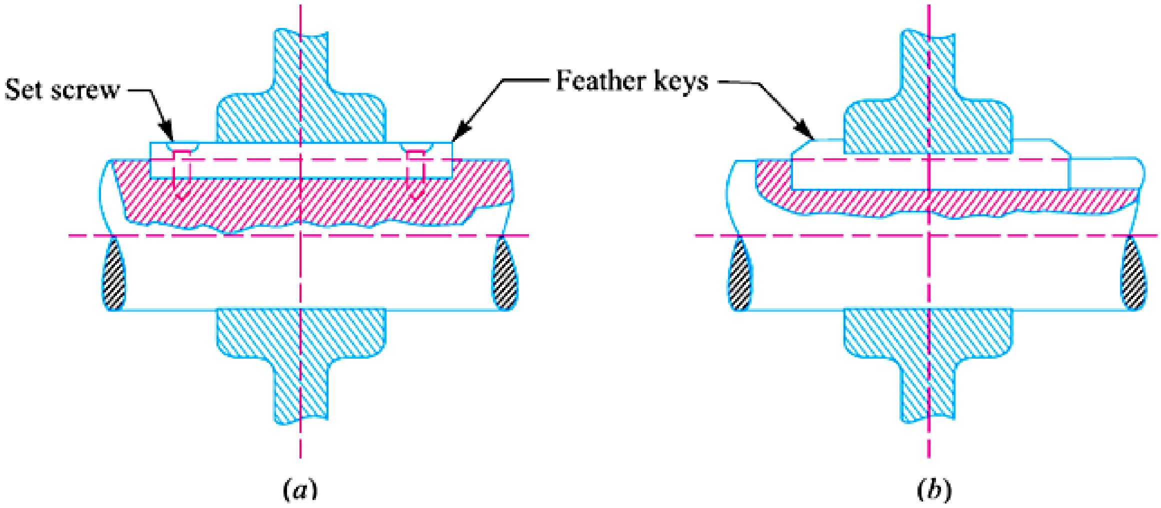
$$w = t = \frac{d}{4}$$

c. parallel sunk key : it is the same of others above just a taper less

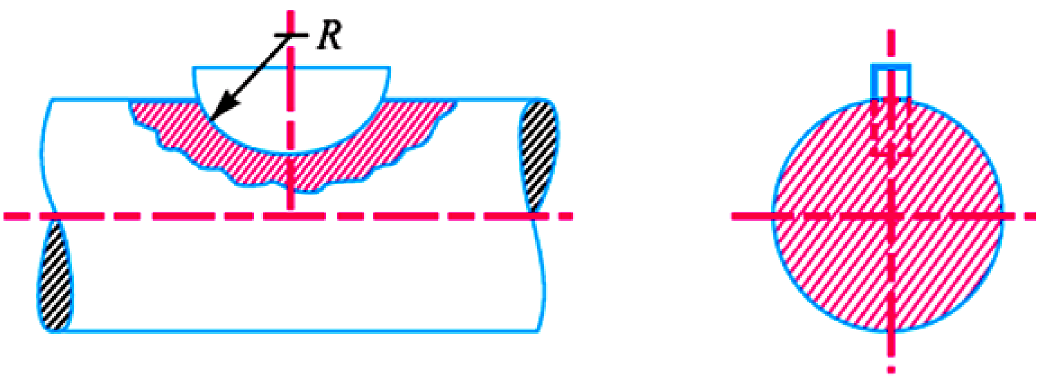
d. Gib head key



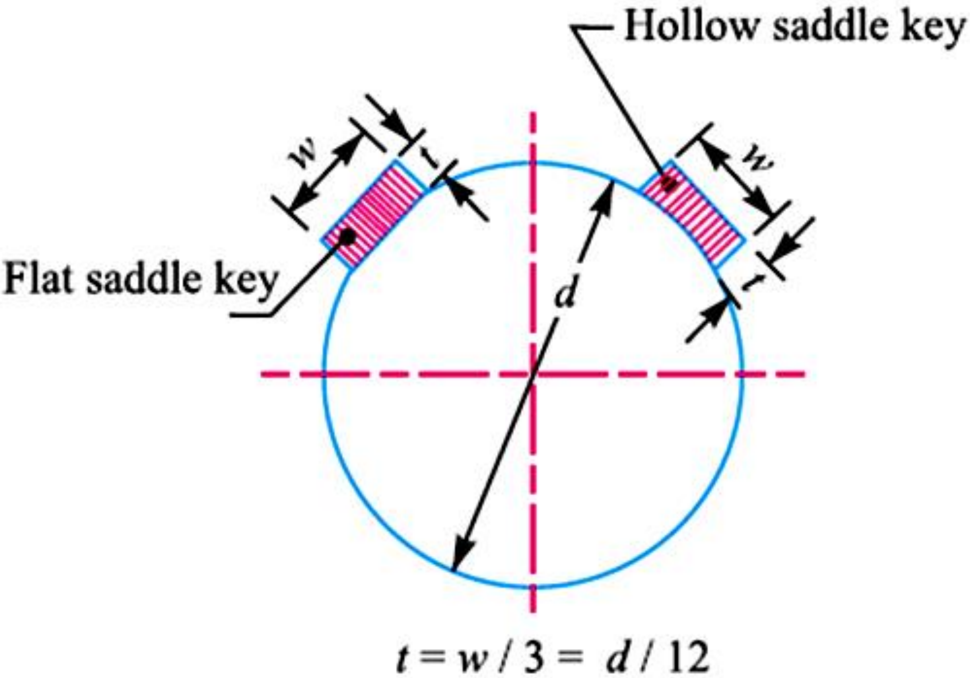
e. feather key :



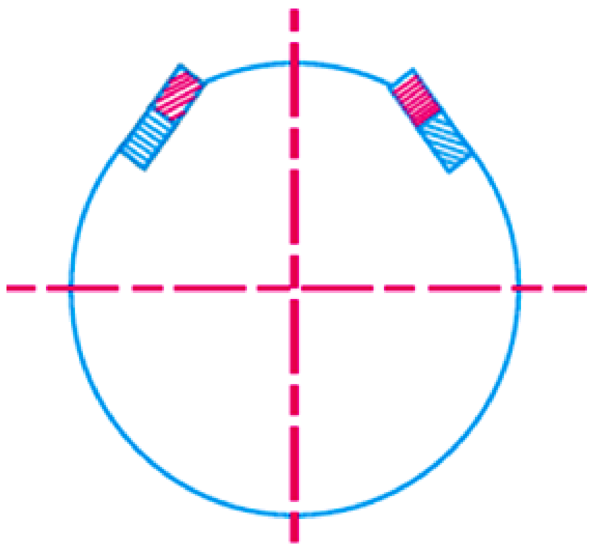
f. woodruff key :



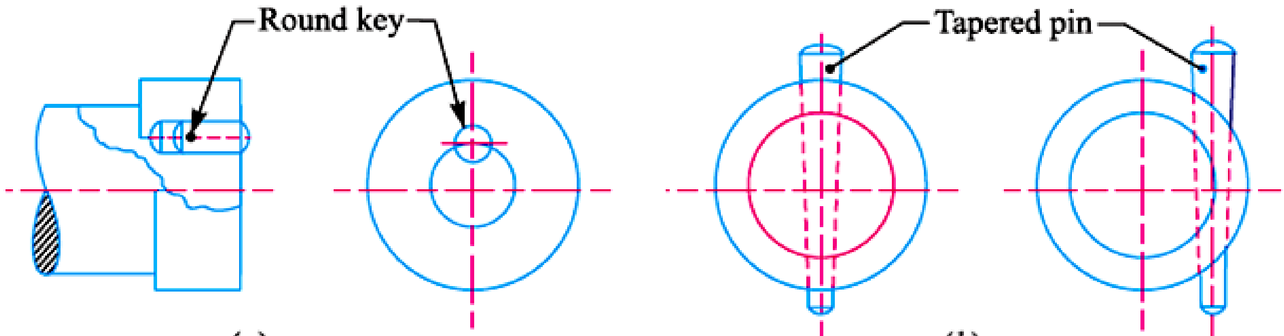
saddle keys



tangent keys



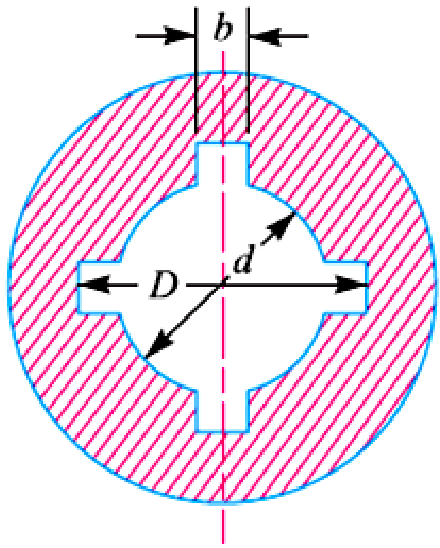
round keys



(a) (b)

splines

these shafts usually have four ,six ,ten ,sixteen splines. the splined shafts are used when the force to be transmitted large in proportion to the size of the shaft.



$D = 1.25\ d$ and $b = 0.25\ D$

Stresses in keys

1.shear stress

$$\tau = \frac{F}{A_s} = \frac{\frac{T}{r}}{l \times w} = \frac{\frac{\frac{T}{d}}{2}}{l \times w} = \frac{2T}{d \times l \times w}$$

A_s - Area resisting shear

T - transmitted torque

w - width of key

l - length of the key

r – radius of shaft

2.Crushing stress

$$S_c = \frac{F}{A_c} = \frac{\frac{T}{r}}{\frac{t}{2} \times l} = \frac{\frac{\frac{T}{d}}{2}}{\frac{t \times l}{2}} = \frac{4T}{d \times t \times l}$$

t - thickness of key

A_c - area resisting crushing

S_c - crushing stress

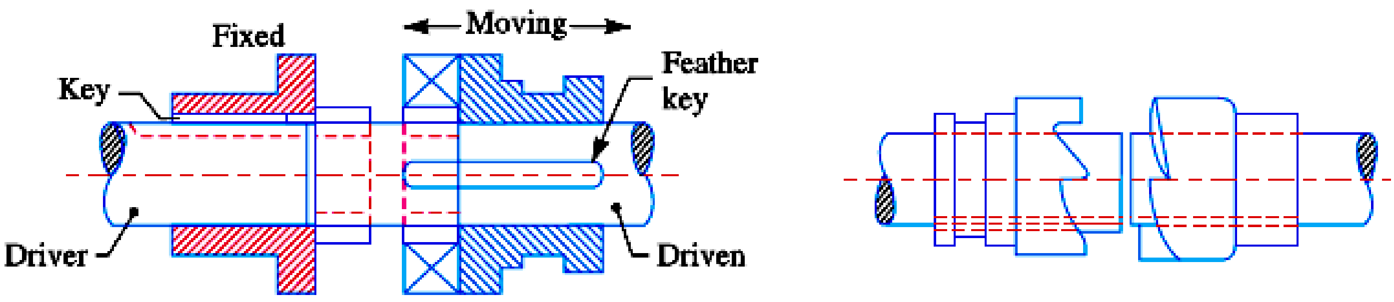
Friction clutches

Clutches :   clutch is a machine member used to connect a driving shaft to a driven shaft , so that the driven shaft may be started or stopped at will, without stopping the drive shaft.

Types of clutches :

There are two main types of clutches:

1.positive clutches

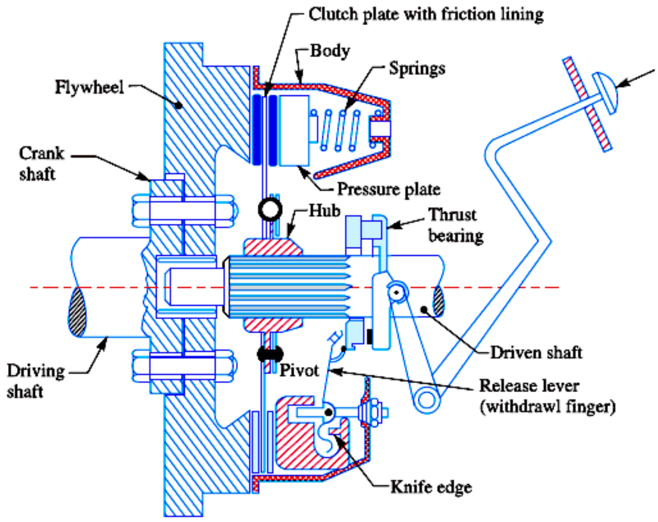


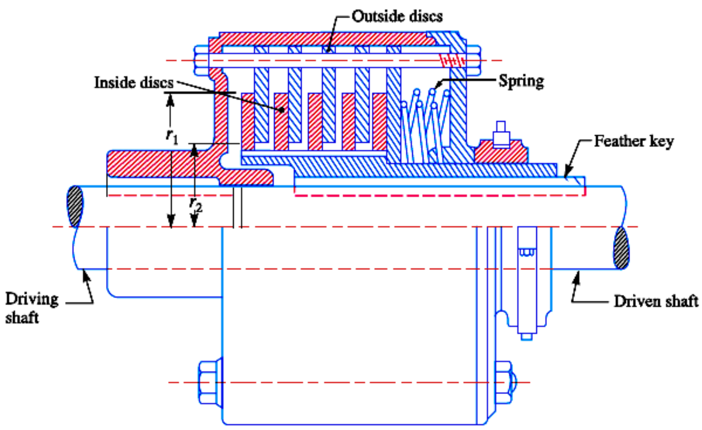
(a) Square jaw clutch.

(b) Spiral jaw clutch.

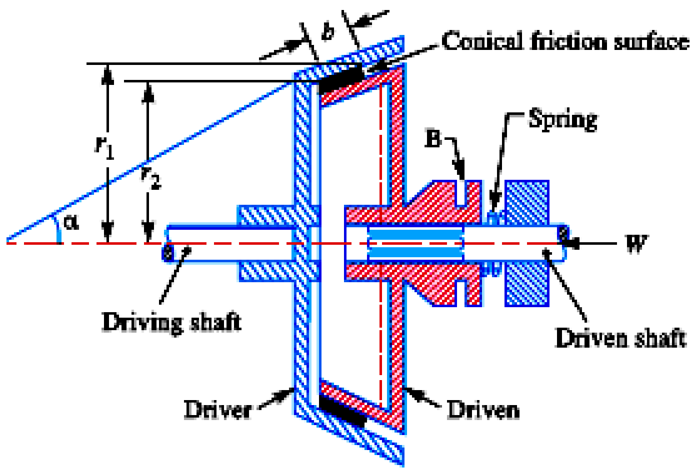
2.friction clutches

(a)disc or plate clutches

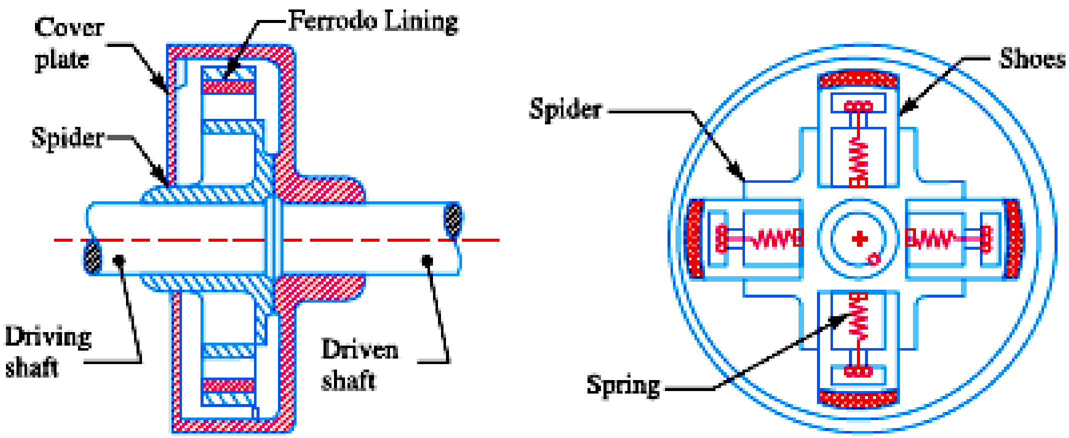




(b)cone clutches



(c)centrifugal clutches

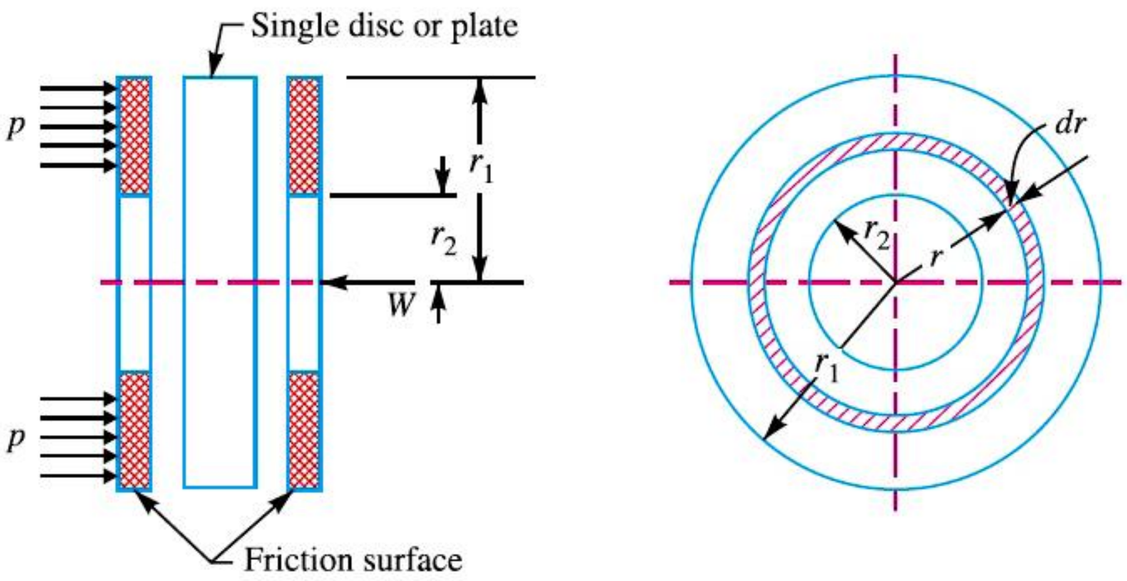


Note: the disc and cone clutches are known as ***axial friction clutches***, while the centrifugal clutch is called ***radial friction clutch***.

Properties of materials commonly used for lining of friction surfaces.

Material of friction surfaces	*Operating condition*	*Coefficient of friction*	*Maximum operating temperature (°C)*	*Maximum pressure (N/mm^2)*
Cast iron on cast iron or steel	dry	0.15 – 0.20	250 – 300	0.25– 0.4
Cast iron on cast iron or steel	In oil	0.06	250 – 300	0.6 – 0.8
Hardened steel on Hardened steel	In oil	0.08	250	0.8 – 0.8
Bronze on cast iron or steel	In oil	0.05	150	0.4
Pressed asbestos on cast iron or steel	dry	0.3	150 – 250	0.2 – 0.3
Powder metal on cast iron or steel	dry	0.4	550	0.3
Powder metal on cast iron or steel	In oil	0.1	550	0.8

Design of a disc clutch:



Consider two friction surfaces maintained in contact by an axial thrust (*W*) :

T – torque transmitted by the clutch

P – axial pressure with which the contact surfaces are held together

r_1 and r_2 – external and internal radii of friction faces

consider an elementary ring of radius r and thickness dr :

then the area of contact surface $A = 2\pi r.dr$

$\therefore$ axial force on the ring

$$\delta W = pressure \times Area = p \times A = p \times 2\pi r.dr$$

And the frictional force on the ring acting tangentially at radius r :

$$F_r = \mu \times \delta W = \mu.p \times 2\pi r.dr$$

$\mu - coefficient\ of\ friction$

$\therefore$ frictional torque acting on the ring

$$T_r = F_r \times r = \mu.p \times 2\pi r.dr \times r = 2\pi \mu.p.r^2\,dr$$

We shall considering two cases :

1.uniform pressure

2.uniform axial wear

1.when we have uniform pressure

$$p = \frac{W}{\pi[(r_1)^2 - (r_2)^2]}$$

$$T = \mu.W.R$$

$$R = \frac{2}{3}\left[\frac{(r_1)^3 - (r_2)^3}{(r_1)^2 - (r_2)^2}\right]$$

W – axial thrust on the friction surfaces

T – total friction torque

R – mean radius of the friction surface

2.when we have uniform wear

The normal wear is proportional to the work of friction. The work of friction is proportional to the product of normal pressure *(p)* and the sliding velocity *(V):*

normal wear $\propto$ work of friction $\propto p \,.\, V$

$$-\ i\ - \qquad p\,.\,V = K \qquad (K - constant)$$

$$p = \frac{K}{V}$$

$$p \times r = C \qquad (C - constant) \qquad -\ ii\ -$$

$$p = \frac{C}{r}$$

$$r - distance\ \ from\ the\ axis\ of\ \ clutch$$

$$\delta W = pressure \times Area = p \times A = \ p \times 2\pi\, r\,.dr$$

$$\delta W = \frac{C}{r} \times 2\,\pi\, r\,.dr = 2\,\pi\, C.dr$$

$$\therefore W = 2\pi\, C\,(r_1 - r_2)$$

$$C = \frac{W}{2\,\pi\,(r_1 - r_2)}$$

$$T_r = F_r \times r = \mu . p \times 2\pi r . dr \times r = 2\pi \mu . p . r^2 dr$$

$$T_r = 2\pi \mu \times \frac{C}{r} \times r^2 \ dr = 2\pi . \mu . C . r \, dr$$

$$\therefore T = \pi \mu C \left[(r_1)^2 - (r_2)^2 \right] = \pi \mu \times \frac{W}{2\pi (r_1 - r_2)} \times \left[(r_1)^2 - (r_2)^2 \right]$$

$$= \frac{1}{2} \mu W (r_1 + r_2) = \mu . W . R \qquad R = \frac{r_1 + r_2}{2}$$

: 1. In general, total frictional torque acting on the friction surfaces (or on the clutch) is given by

$$T = n.\mu.W.R$$

where

n = Number of pairs of friction (or contact) surfaces, and

R = Mean radius of friction surface

$$= \frac{2}{3}\left[\frac{(r_1)^3 - (r_2)^3}{(r_1)^2 - (r_2)^2}\right] \quad \text{... (For uniform pressure)}$$

$$= \frac{r_1 + r_2}{2} \quad \text{... (For uniform wear)}$$

2. For a single disc or plate clutch, normally both sides of the disc are effective. Therefore a single disc clutch has two pairs of surfaces in contact (*i.e.* $n = 2$).

3. Since the intensity of pressure is maximum at the inner radius (r_2) of the friction or contact surface, therefore equation (*ii*) may be written as

$$p_{max} \times r_2 = C \quad \text{or} \quad p_{max} = C / r_2$$

4. Since the intensity of pressure is minimum at the outer radius (r_1) of the friction or contact surface, therefore equation (*ii*) may be written as

$$p_{min} \times r_1 = C \quad \text{or} \quad p_{min} = C / r_1$$

5. The average pressure (p_{av}) on the friction or contact surface is given by

$$p_{av} = \frac{\text{Total force on friction surface}}{\text{Cross-sectional area of friction surface}} = \frac{W}{\pi[(r_1)^2 - (r_2)^2]}$$

6. In case of a new clutch, the intensity of pressure is approximately uniform, but in an old clutch, the uniform wear theory is more approximate.

7. The uniform pressure theory gives a higher friction torque than the uniform wear theory. Therefore in case of friction clutches, uniform wear should be considered, unless otherwise stated.

Springs

Spring is an elastic body compressed or extended when loaded , and go to its original shape when load is removed.

The important applications of springs are as follows :

1.to apply forces, as in brakes, clutches and spring loaded valves

2.to control motion by maintaining contact between two elements as in cams and followers.

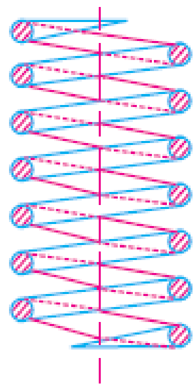
3.to measure forces, as in spring balances and engine indicators

4.to store energy, as in watches, toys, etc..

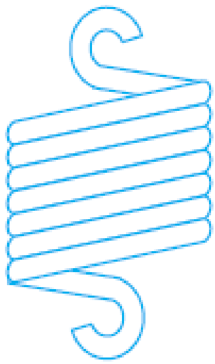
5.to absorb or control energy due to either shock or vibration, as in car spring, aircraft landing gears, shock absorbers and vibration dampers.

Types of springs

1.helical springs

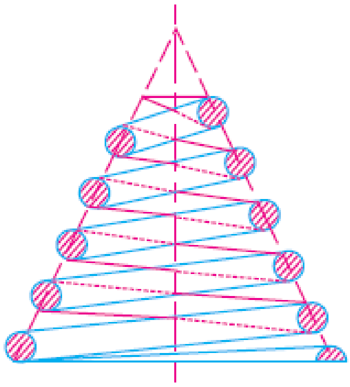


(*a*) Compression helical spring.

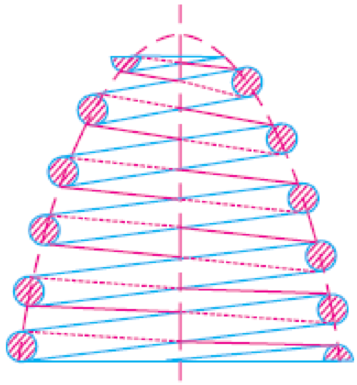


(*b*) Tension helical spring.

2.conical and volute springs

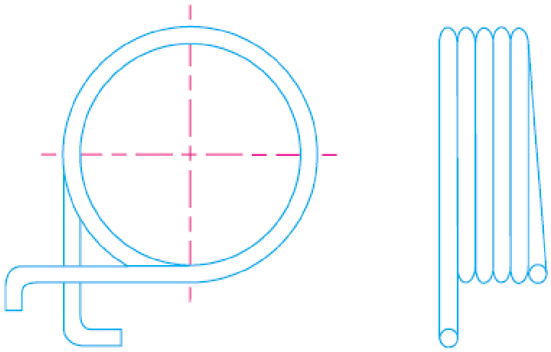


(*a*) Conical spring.

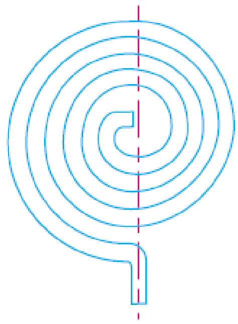


(*b*) Volute spring.

3.torsion springs

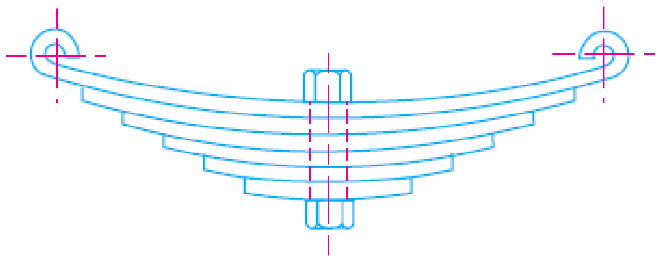


(*a*) Helical torsion spring.

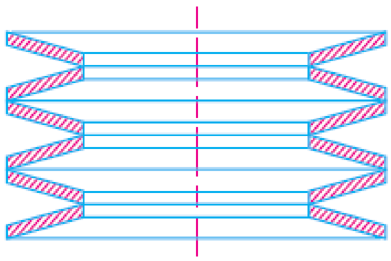


(*b*) Spiral torsion spring.

4.laminated or leaf springs



5.disc springs



Terms used in compression springs

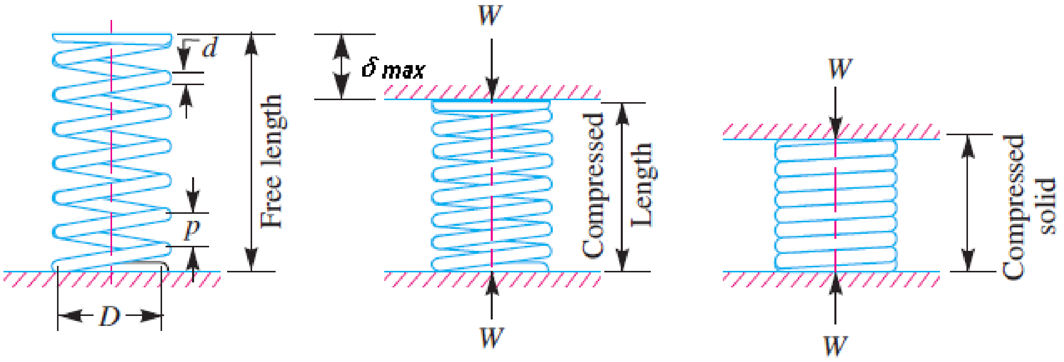
1.solid length: it's the product of total numbers of coils and the diameter of the wire

$$L_S = n' \times d$$

$$n' - total\ number of\ coils$$

$$d - diameter of\ wire$$

2. free length : it's the length of spring in the free or unloaded condition.



Free length = solid length +max. compression +clearance between adjacent coils

$$L_F = n' \times d + \delta_{\max} + 0.15\,\delta_{\max}$$

We can also use the following relation to find the free length of spring

$$L_F = n' \times d + \delta_{\max} + (n' - 1) \times 1mm$$

The clearance is taken as 1 mm

3. spring index : it's the ratio of the mean diameter of the coil to the mean diameter of wire

$$C = \frac{D}{d}$$

4. spring rate : it's the load required per unit deflection of the spring

$$k = \frac{W}{\delta}$$

5. pitch : it means the axial distance between adjacent coils in uncompressed state.

$$P = \frac{free\ \ length}{n^{'} - 1} = \frac{L_F}{n^{'} - 1}$$

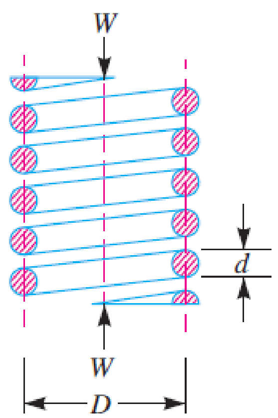
The pitch may also be obtained by using the following relation

$$P = \frac{L_F - L_S}{n^{'}} + d$$

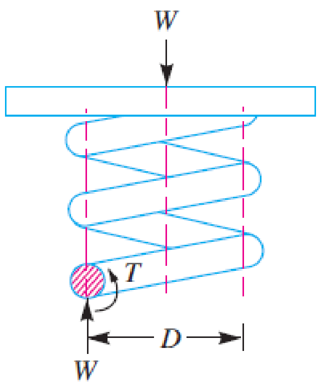
$$L_F - free\,length$$

$$L_S - solid\,length$$

Stresses in helical springs of circular wire



(*a*) Axially loaded helical spring.



(*b*) Free body diagram showing that wire is subjected to torsional shear and a direct shear.

$$T = W \times \frac{D}{2} = \frac{\pi}{16} \times \tau_1 \times d^3$$

$$\tau_1 = \frac{8WD}{\pi d^3}$$

$$\tau_1 - torsional shear stress$$

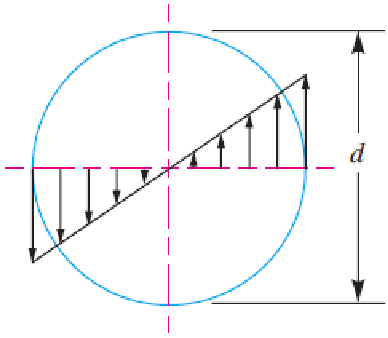
The following stresses also act on the wire

1.direct shear stress because of the load W

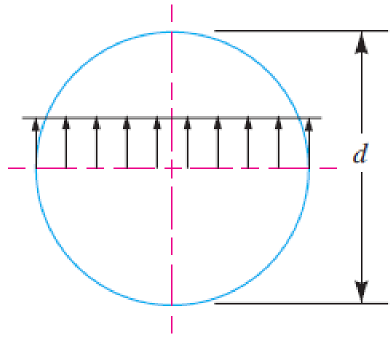
$$\tau_2 = \frac{load}{cross-sectional area of\ the\ wire}$$

$$\tau_2 = \frac{W}{\frac{\pi}{4} \times d^2} = \frac{4W}{\pi d^2}$$

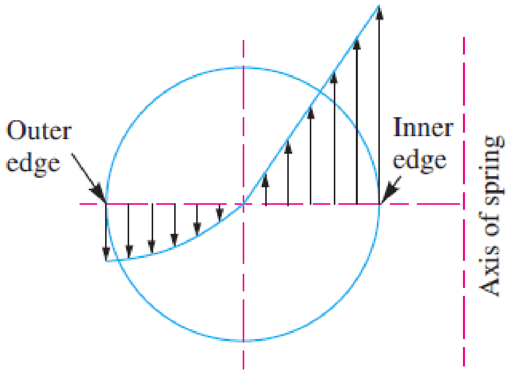
2.stress due to curvature of wire



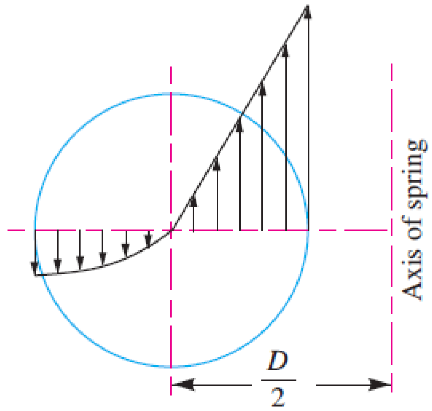
(*a*) Torsional shear stress diagram.



(*b*) Direct shear stress diagram.



(*c*) Resultant torsional shear and direct shear stress diagram.



(*d*) Resultant torsional shear, direct shear and curvature shear stress diagram.

Maximum shear stress in the wire = torsional shear stress + direct shear stress

$$\tau_{max} = \tau_1 + \tau_2$$

$$= \frac{8\,W\,D}{\pi\,d^3} + \frac{4\,W}{\pi\,d^2} = \frac{8\,W\,D}{\pi\,d^3}\left(1 + \frac{d}{2D}\right) \qquad if\ \frac{D}{d} = C$$

$$\tau_{max} = \frac{8\,W\,D}{\pi\,d^3}\left(1 + \frac{1}{2C}\right) = K_S \times \frac{8\,W\,D}{\pi\,d^3}$$

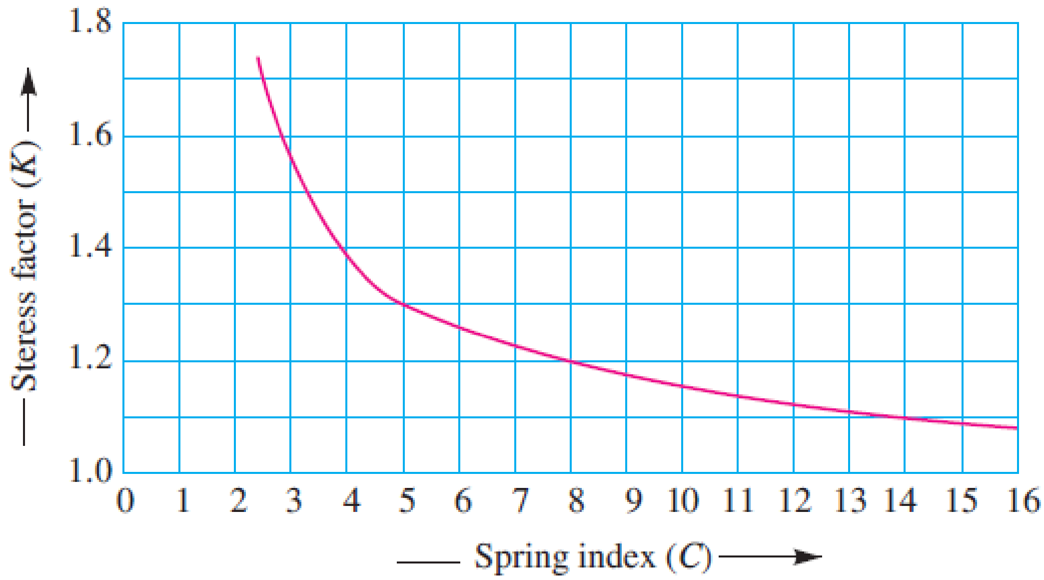
$$where\ K_S = 1 + \frac{1}{2C} \qquad shear stress\ factor$$

In order to consider the effects of both direct shear stress as well as curvature of the wire we use a Wahl's stress factor.

Maximum shear stress in the wire

$$\tau = K \times \frac{8\,W\,D}{\pi\,d^3} = K \times \frac{8\,W\,C}{\pi\,d^2}$$

$$K = \frac{4\,C - 1}{4\,C - 4} + \frac{0.615}{C}$$ *Wahl's stress factor*



Wahl's stress factor for helical springs.

Deflection of helical springs of circular wire

$$\delta = \theta \times \frac{D}{2}$$

θ – *Angular deflection of wire*

$$\theta = \frac{16\, W\, D^2\, n}{G\, d^4}$$

$$\delta = \frac{16\, W\, D^2\, n}{G\, d^4} \times \frac{D}{2} = \frac{8\, W\, D^3\, n}{G\, d^4} = \frac{8\, W\, C^3\, n}{G\, d}$$

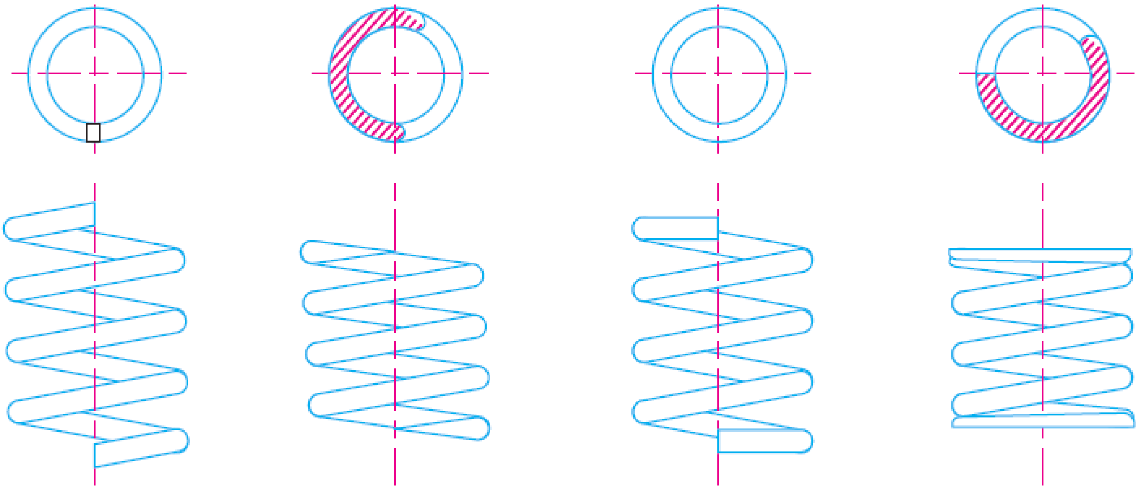
n – *number of active turn*

G – *modulus of rigidity for the material of spring wire*

$$\frac{\delta}{n} = \frac{8\, W\, D^3}{G\, d^4} = \frac{8\, W\, C^3}{G\, d} \qquad \textit{deflection per active turn}$$

Spring rate or stiffness of the spring

$$\frac{W}{\delta} = \frac{G\, d^4}{8\, D^3\, n} = \frac{G\, d}{8\, C^3\, n} \text{ =constant}$$



(*a*) Plain ends. (*b*) Ground ends. (*c*) Squared ends. (*d*) Squared and ground ends.

Type of end	*Total number of turns (n')*	*Solid length*	*Free length*
1. Plain ends	n	$(n + 1)\ d$	$p \times n + d$
2. Ground ends	n	$n \times d$	$p \times n$
3. Squared ends	$n + 2$	$(n + 3)\ d$	$p \times n + 3d$
4. Squared and ground ends	$n + 2$	$(n + 2)\ d$	$p \times n + 2d$

where n = Number of active turns,

p = Pitch of the coils, and

d = Diameter of the spring wire.

SWG	*Diameter (mm)*	*SWG*	*Diameter (mm)*	*SWG*	*Diameter (mm)*	*SWG*	*Diameter (mm)*
7/0	12.70	7	4.470	20	0.914	33	0.2540
6/0	11.785	8	4.064	21	0.813	34	0.2337
5/0	10.973	9	3.658	22	0.711	35	0.2134
4/0	10.160	10	3.251	23	0.610	36	0.1930
3/0	9.490	11	2.946	24	0.559	37	0.1727
2/0	8.839	12	2.642	25	0.508	38	0.1524
0	8.229	13	2.337	26	0.457	39	0.1321
1	7.620	14	2.032	27	0.4166	40	0.1219
2	7.010	15	1.829	28	0.3759	41	0.1118
3	6.401	16	1.626	29	0.3454	42	0.1016
4	5.893	17	1.422	30	0.3150	43	0.0914
5	5.385	18	1.219	31	0.2946	44	0.0813
6	4.877	19	1.016	32	0.2743	45	0.0711

خارطة القياس المعتمدة

المحتوى التعليمي	عناوين الفصول	الأهمية النسبية	الأهداف السلوكية					عدد الفقرات
			المعرفة	الفهم	التطبيق	التحليل	التقييم	
الفصل الاول	Review of Strength of Materials	%100	%35	%25	%10	%10	%20	5
الفصل الثاني	Screwed Joints	%100	%35	%25	%10	%10	%20	5
الفصل الثالث	Welded Joints	%100	%35	%25	%10	%10	%20	5
الفصل الرابع	Frictional Clutches	%100	%35	%25	%10	%10	%20	5
المجموع								