# STUDY OF MECHANICAL JOINTS

I. Introduction

A mechanism is a set of parts connected to each other by kinematic links in order to perform a specific function.

Establishing a connection between 2 parts means removing a certain number of degrees of freedom between these parts to leave only those necessary for the desired operation.

I.1 Degrees of freedom and degrees of bonding:

The **degrees of freedom (degré de liberté)** of a **joint (liaison)** between two solids *S1* and *S2* correspond to the independent relative motions allowed within this joint between *S1* and *S2*. 6 possible elementary motions of a solid in space relative to a coordinate system (A,x,y,z):

    1- 3 translations: Tx, Ty, Tz,
    2- 3 rotations: Rx, Ry, Rz.
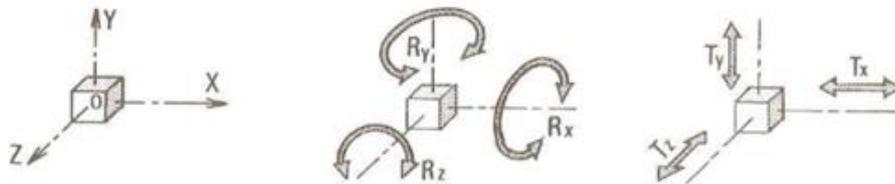
Let m be the degree of freedom of a joint. The **degree of connection** of a joint is, in space, $6 - m$

I.2 Elementary and compound joints

An elementary joint between two solids S1 and S2 is obtained from the contact of an elementary geometric surface attached to S1 on an elementary geometric surface attached to S2. The elementary geometric surfaces obtained from the main machining processes are the plane, the cylinder and the sphere.

A compound joint is obtained by coherent association of elementary joints.

The following table gives the different possible associations.

II. Modeling a mechanism

Since a mechanism is an organized set of solids and joints, it is essential to make an analysis and a logical representation of it, in accordance with its structure. To do this, we have appropriate tools:

1. The **structure graph** (or joints graph) and the **kinematic diagram (schéma cinématique)** in the case of a geometric and/or kinematic study;

2. **The graph of the joints and forces**, and the architecture diagram in the case of a study of the forces in the links, in static or dynamics.

The kinematic analysis of a mechanism begins with the identification of the kinematically linked groups and the contact surfaces that link them (joints), which allows to construct its structure graph and kinematic diagram.

Joint	Standardized Planar Representation	Standardized Spatial Representation	Degrees of Freedom
Point Contact Joint (ponctuelle) with center O and normal $\hat{z}$			Rotations: R_x, R_Y, Rz Translations: T_x, T_Y, 0
Rectilinear Line Contact Joint (linéique rectiligne) with axis (O $\hat{y}$) and normal $\hat{z}$			Rotations: 0, R_Y, Rz Translations: T_x, T_Y, 0
Annular Line Contact Joint (Linéique annulaire) with axis (O $\bar{x}$)			Rotations: R_x, R_Y, Rz Translations: T_x, 0, 0
Spherical Joint (Ball-and-Socket) (rotule) with center O			Rotations: R_x, R_Y, Rz Translations: 0, 0, 0
Spherical Joint with a Pin (Rotule à doigt) (axes O $\hat{y}$ and O $\bar{z}$)			Rotations: 0, R_Y, Rz Translations: 0, 0, 0

Joint	Standardized Planar Representation	Standardized Spatial Representation	Degrees of Freedom
Plan Support Joint (appui plan) with normal $\hat{z}$			Rotations: 0, 0, Rz Translations: Tx, Ty, 0
Sliding Pivot Joint (pivot glissant) with axis (O $\bar{x}$)			Rotations: Rx, 0, 0 Translations: Tx, 0, 0
Helical (Screw) Joint (glissière hélicoïdale) with axis (O $\bar{x}$)			Proportional relationship: Rx ↔ Tx Other: 0, 0, 0
Slider Joint (glissière) with direction $\bar{x}$			Rotations: 0, 0, 0 Translations: Tx, 0, 0
Pivot Joint (pivot) with axis (O $\bar{x}$)			Rotations: Rx, 0, 0 Translations: 0, 0, 0
Fixed (Clamped) Joint (encastrement)			Rotations: 0, 0, 0 Translations: 0, 0, 0

II.1 Minimum kinematic diagram (block diagram)

This mode of representation highlights the relative movements between kinematic subsets. Unlike the architectural plan, we are not interested in the construction of links but only in mobility. It is subject to the NF EN 23-952 standard.

The connections are assumed to be perfect: the geometric surface is perfect, the internal play of the connection is neglected, friction is neglected.

The kinematic diagram must present as faithfully and simply as possible the relationships between the different groups of parts. We will therefore find:

1. Groups of parts represented in the form of "wires". They are also called "kinematic blocks" or "equivalence classes"
2. Standardized connections located at each contact between the parts groups.

The main steps in making a kinematic diagram are presented below:

Step 1: Identify the **kinematic groups**
  - Color the equivalence classes on the overall map
  - Identify the parts that make up each group (the elastic parts to be excluded)

Step 2: Establish the joints graph
 - To link by a line the groups having contacts of any kind.

Step 3: Identify the connections between the groups:
  - Determine the nature of the contact(s) between the equivalency classes. and/or observe the degrees of freedom between the groups concerned.
  - Derive the corresponding normalized connection (center and axis)

Step 4: Build the minimum kinematic diagram
  - Choose the most explicit point of view for the schema (x,y plane)
  - Identify the relative position of the links (in the center of the real contact)
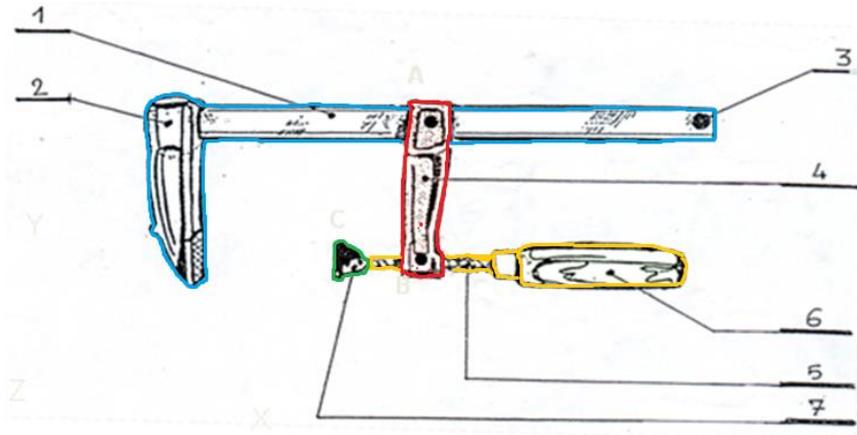
Example: Clamps
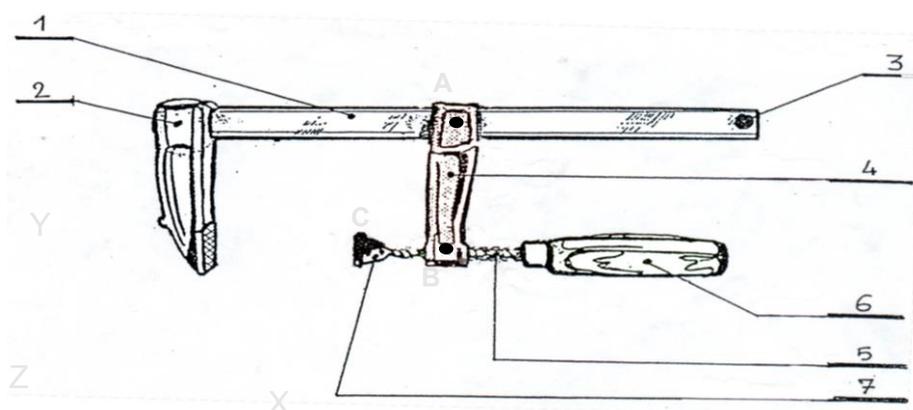
Step 1: kinematic groups (equivalence classes)
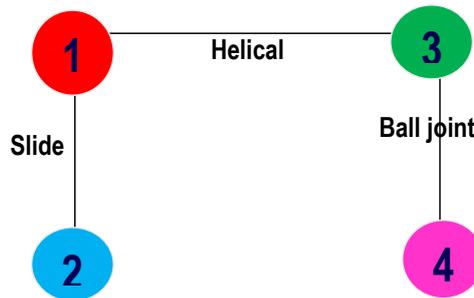
Group 1: 4
Group 2: 1; 2 ; 3
Group 3: 6; 5
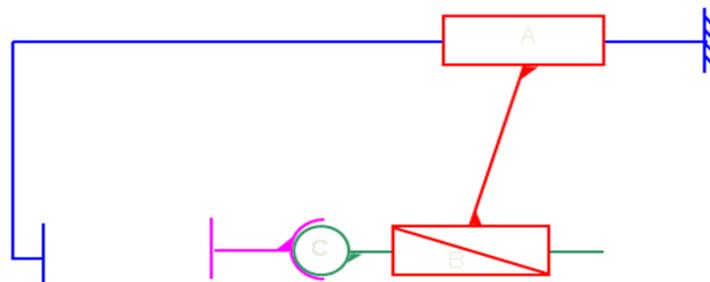**Group 4: 7**

Step 2/3: Link graph

Step 4: Minimum kinematic diagram

II.2 Characterization of a binding by transmissible forces:

An embedding connection makes it possible to transmit a mechanical action that can be represented by:

$$\{\mathcal{T}_{s1/s2}\} = \begin{vmatrix} X & L \\ Y & M \\ Z & N \end{vmatrix}_{(A,\, x,\, y,\, z)}$$

Where X, Y, Z are the components of a force and L, M, N that of a moment in the basis under consideration

If a joint has a degree of mobility, one of the six components of the transmissible mechanical action is zero. For example, in a perfect X-axis pivot link, the X-axis torque is zero. So we always have:

Number of degrees of freedom = number of null action components

III. Technological aspects of the joints:
III.1 Technical characterization of a joint

A connection between two parts of a mechanism has 5 characters:

1. the number of degrees of freedom,
2. the permanence of the joint,
3. the deformability of the joint,
4. the transfer of a share
5. the existence or not of organs associated with the realization of the joint.
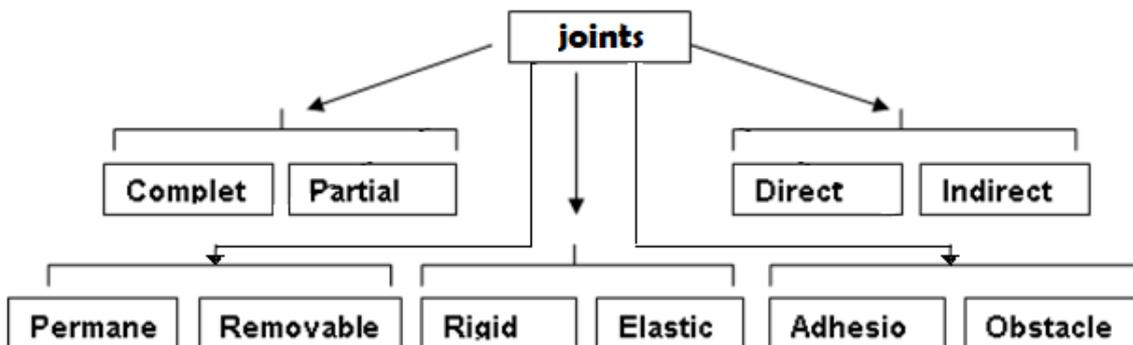
III.2 Choice of joints

When choosing links, the following technological factors must be taken into account:

1. Functional conditions.
2. The nature and intensity of the forces applied to the assembled parts.
3. The possibility and method of machining.

4. The frequency and ease of disassembly.

5. The congestion (encombrement) of the connecting organs.

6. The cost (price).

III.3 Construction of joints

A mechanism is a set of organs subject to joints. These ensure the relative, total or partial immobilization of two adjacent parts. To ensure the connections, accessory components or technological elements whose shape and dimensions have been standardized are used in most cases. These components are not shown on the working drawings and are shown in the nomenclatures with their full standardised designation.

The table below indicates, for each type of connection, the various possible realizations and the means of connection used.

NATURE OF THE JOINTS	MEANS OF THE JOINTS
Complete and non-removable	- Rivets - Cylindrical shanks (Emmanchements cylindriques) with high clamping -Welds (Soudures)
Complete removable	- Bolt, stud (goujons) and screw connection - Tapered shank (Emmanchement conique) - Forced keying (Clavetages forces) - Gouges (Goupillages) - Pressure screw locks, melted bushings and cams (douilles fondues et cames)
Partial in translation	- Shoulders or bases (Épaulement ou embases) - Clamps or stop rings (Brides ou bagues d'arrêt) - Washers and nuts or pins or screws (goupilles ou vis) - Nipple screws (Vis à téton) - Tangent pins (Goupilles tangents) - Circlips
Partial in rotation	- Non-cylindrical shanks - Disc or parallel keys (Clavettes disques ou parallèles) - Fluted shafts (Arbres cannelés) - Serrated shafts (Arbres dentelés) - Nipple screws (Vis à téton) -Tabs (Ergots)
Partial articulation	-Kneecaps (Ressorts) - Axle (axes) -screws - Hinge pins (Axes d'articulation)

Partial elastic	-Resorts - Belleville washers (Rondelles) -Rubber (Caoutchouc) - Silent block (Silentbloc)