

INNOVATIVE MECHANISM DESIGN WITH CAE SOFTWARE

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ABSTRACT

This paper presents a mechanical design problem, given to students, in which a creative engineering activity is clearly illustrated. The work organization and the imposed instructions are determinant factors that involve innovative and industrial working conditions. Mechanisms proposed by students are discussed. Several aspects that characterize the advantages of the design in group are described.

Keywords: Innovation, creativity, mechanism design, CAE, transmission, wiper.

1 INTRODUCTION

Mechanical design is a domain where creativity plays an important role. These last twenty years, the growth of Computer Aided Design (CAD) and Computer Aided Engineering (CAE) gave the illusion that computers were able to take in charge this creative aspect of the designer work. In fact, the CAD acronym remains highly optimistic on the inner capacities of computers and software. Even though modern designer uses extensively CAD/CAE software, most of the creative impulsion is still taken in charge by human brain. As shown in [1] and to our knowledge, there are no commercial creative CAD software for the moment even though research CAD software already exist for structural synthesis (decomposition approach with constraint rules and case-based reasoning or other artificial intelligence techniques).

Students at the French Institute for Advanced Mechanics (IFMA) follow many design methodology lectures, use lots of CAD/CAE software and sometimes tend to neglect their own creative capacities. In second year, during the Mechanism and Robotics course, they were given a new type of exercise in order to make them realize importance of creativity and improve their ability to be creative. The main difficulty we were confronted with is the subject definition. In fact, a creative design problem is not simply a dimensioning problem and it must remain open to the variety of solutions that students may propose. On the other hand, the work evaluation becomes quite delicate since precise cost estimation and experimental verification of proposed solutions can not be performed.

In the next section, the mechanical design problem is presented. Several instructions given to students in order to motivate creativity are listed. Indications for work evaluation are given. In the following section, an attempt to analyze and classify the proposed mechanisms is presented. In fact, for a creative problem, it is quite important to be able to define evaluation criteria for benchmarking a high number of potential mechanisms [1,2]. Some typical and particular mechanisms illustrate the diversity of the design solutions.

2 PROBLEM SETTING

2.1 The creative problem

The work consists in designing a mechanism for a windshield wiper. It was proved in previous research work [2,3] that such classes of mechanisms (transmission mechanisms with one input and one or several outputs) contain an extremely large number of mechanisms that can be restricted progressively to a limited number of interesting solutions. In that case, a set of forty basic elementary stages coming from mechanism encyclopedias [4] are provided, though the students are not limited to them (Fig. 2). For each stage, average data such as attainable ratio range or efficiency (if available) are provided.

The objective of the task for each group of students was not to obtain the best solution but to explore diversity, to choose one acceptable solution and to justify their choice. Difficulty is to find the good combination of stages and to make preliminary design of them. The stress is explicitly laid on uniqueness : all the students with the same solutions are severely penalized, in order to force young designer minds to explore new concepts.

The windshield wiper mechanism has one input for an electric motor and two outputs for moving the wipers (Fig. 1). Using a reference frame (O, x, y, z) set at the basement of the windshield, all the following constraints are expressed in millimeters. The requirements are :

- Mechanism must be included in a **maximum bounding box** defined by two diagonal points P_{MIN} and P_{MAX} with : $P_{MIN} = (500, -150, -150)$ and $P_{MAX} = (1400, 0, 0)$;
- **Input movement** is a continuous rotation created by a DC electric motor connected on input point $P_I = (500, -75, -75)$ with input axis parallel to x axis.
- **Output movements** are alternate rotations around z axis located on output points $P_{O1} = (850, -75, -0)$ and $P_{O2} = (1350, -75, -0)$. Rotations start from vertical position on a range of 80° .
- **Transformation ratio**: the electric motor runs at 1200 rpm for one wiping cycle frequency of 1 Hz , which means twenty rotations for one wiping cycle.
- **Efficiency** must be over 70% when it is possible to calculate it.

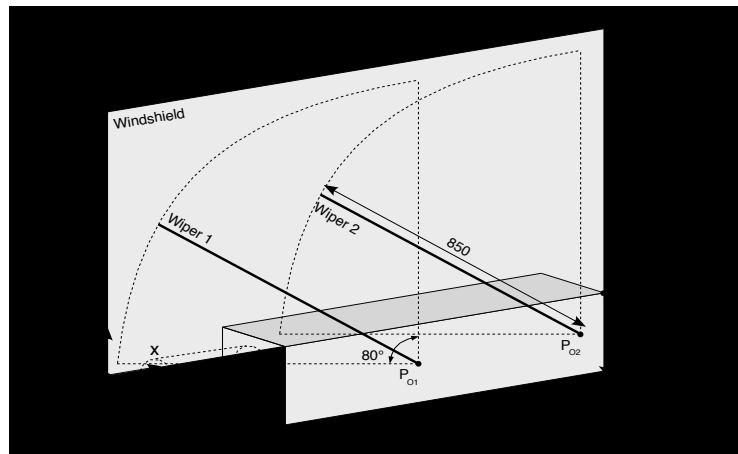


Figure 1. Surroundings of the mechanism to design.

2.2 Problem instructions

Each student is supposed to produce a written document containing four sections :

- Section 1 – Manual search for concepts: each one should be described in a few sentences with kinematic schemes complying with official standards.
- Section 2 – The chosen solution: a full page detailed kinematic sketch with at least two views and a small explanatory description.
- Section 3 – Validating solution: every requirement from specifications should be checked separately here with detailed calculations.
- Section 4 – Technical analysis: every remark on technical feasibility and inner qualities or disadvantages of the chosen mechanism are presented here.

A virtual model of the mechanism is also supposed to be created with ADAMS software. Both documents are evaluated, as well as solution originality and compliance to specifications.

2.3 Organization of the work

Each work is accomplished by two students. Stress is laid to solution originality. Students are encouraged to see what is done by their colleagues. It is important to notice that design problem has a large number of admissible solutions. Students are not penalized if they don't find the best one provided that they are able to present its disadvantages with a sufficiently critical point of view.

2.4 Evaluation of the work

At the end of the work, students defend their proposition during a presentation of 10 minutes. They must demonstrate the correctness of their ADAMS model and the compliance of their design with specifications. To this end, they can use ADAMS measures and post-processor curves. Visual checking of the mechanism packaging can be done by representing the surrounding box as transparent part.

The following indicative mark scales give an overview on how each task is evaluated:

- Design notes (10 points) :
 - Part 1 – manual research (2 points)
 - Part 2 – retained solution (2 points)
 - Part 3 – solution verification (2 points)
 - Part 4 – technological analysis (2 points)
 - the quality of the presentation and the care given to figures, schemes and spelling (2 points)
- ADAMS model (10 points) :
 - Correct running of the model (2 points)
 - Respect of the specifications (4 points)
 - Use of appropriate measures / markers / curves (2 points)
 - Model parametrization and optimization (2 points)

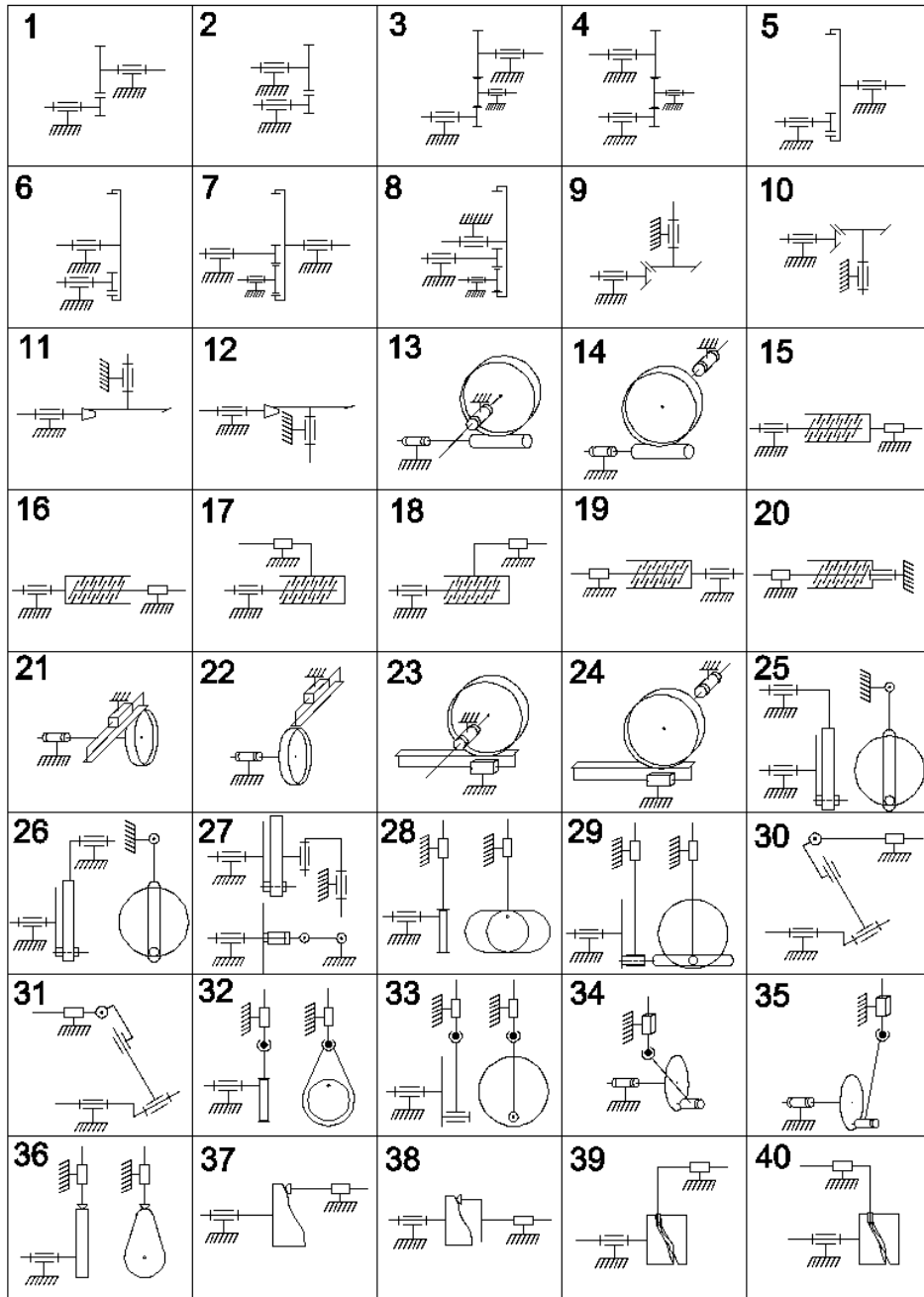


Figure 2. Forty elementary mechanisms

3 THIRTY-FOUR CREATIVE SOLUTIONS

At the end of this work, thirty four different mechanisms are obtained. Solutions of all students are collected in a web page in free access for all the institute. For each group of students, a picture, a video animation and a brief description of the mechanism are provided. In order to have a global point of view on the result of this work, several criteria are defined and used to classify and analyze the proposed solutions:

3.1 Type of chains

We distinguish two types of mechanism chains: planar and spatial chains. The majority of solutions use planar stages (Fig. 3.a, c, d, e, f) even though each stage can be in a different plane. In these cases, bevel gear pairs or screw gear transmissions are used to change the plane of motion. Only four proposed solutions use spatial chains. (Fig. 3.b) with at least one part has a spatial movement.

3.2 Mechanism complexity

In order to characterize the proposed solutions in term of mechanism complexity some indexes can be considered such as the number of links, joints and stages used for each solution. The simplest solution uses 8 joints while the most complex one uses 47 joints. Statistics on mechanism complexity are summarized in Table 1.

3.3 Classification by motion transformation mode

The type of joints used in mechanism design allows us to define two mechanism families. Each family is identified in terms of motion transformation modes between input and output :

- continuous rotation – alternate rotation: this family of mechanism uses exclusively revolute joints (Fig. 3.d, e, f).
- continuous rotation – alternate translation – alternate rotation: this family of mechanisms uses alternate translation to generate alternate rotation at the output level (Fig. 3.a, b, c).

3.4 Mechanism bifurcation

We can also classify mechanisms by considering the adopted techniques to generate an identical movement for the two wipers. The first technique consists in copying the movement of one wiper to the other. In this case, there is a master and a slave wiper (Fig. 3.b, d, f). This is interesting as copying mechanism are generally cheap but may introduce clearance and master wiper overload. The second technique uses a symmetric transmission for the two wipers. In this case, forces applied to each wiper are identical (Fig. 3.a, c, e). This technique is more advantageous for mechanical dimensioning but impose additional geometric constraints.

3.5 Particular solutions

Some proposed mechanisms can be considered as particular. For example, solution presented in Fig. 5.b uses driving belt rather than gear transmission. For other solutions, the alternate output motion is generated by kinematic chain interruption, such as in Fig. 5.a, or kinematic chain commutation. For some solutions, unilateral contacts or cams are used.

3.6 Statistics on joints

As expected, revolute joints are the most employed in design. They appear 283 times in the 34 proposed solutions. This type of joints allows several motion transformations. However, only 8 of the proposed mechanisms use exclusively revolute joints, regardless of gear contacts. We deliberately retain the joint definition used in ADAMS software. Therefore, gears are considered as “technological” joints. They appear in the second position, with 99 occurrences, and they are commonly used for velocity reduction. Prismatic and cylindrical joints are in the third position with 41 occurrences. Joint occurrence statistics are summarized in Fig. 5.

Table 1. Statistics on mechanisms complexity

<i>criteria</i>	<i>minimum</i>	<i>maximum</i>	<i>average</i>
Number of links	6	27	9
Numbers of joints	8	47	16
Number of stages	3	12	4

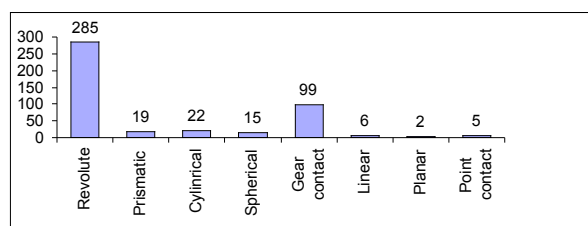


Figure 3. Joint occurrence statistics

3.7 Rules of thumb about designing

Creativity seems to be the main motivation factor for students in this work since they tried to present their own solutions. This creates competitive conditions and stimulates their innovative skills. It presents also an occasion for students to release their creative design capabilities.

This work required precise instructions, particularly for documents to be produced, in order to reach the fixed objectives and facilitate the evaluation. For the students, it was very important to be organized and to communicate together. In fact, to ensure the uniqueness of their solutions, students put a sketch of their solution in a common folder. The shared directory concept was a spontaneous emanation of the hole group.

At the end of this work, an approach can be derived to efficiently perform the design. It is based on considering the design problem in terms of functional blocks. Four functional blocks can be identified:

- reduction of the input rotational velocity,
- change of the plane of motion,
- transformation of the continuous input rotation to an alternate output rotation,
- bifurcation of the output motion into two wipers.

Students who adopted this approach obtained simpler, more efficient and more economic solutions.

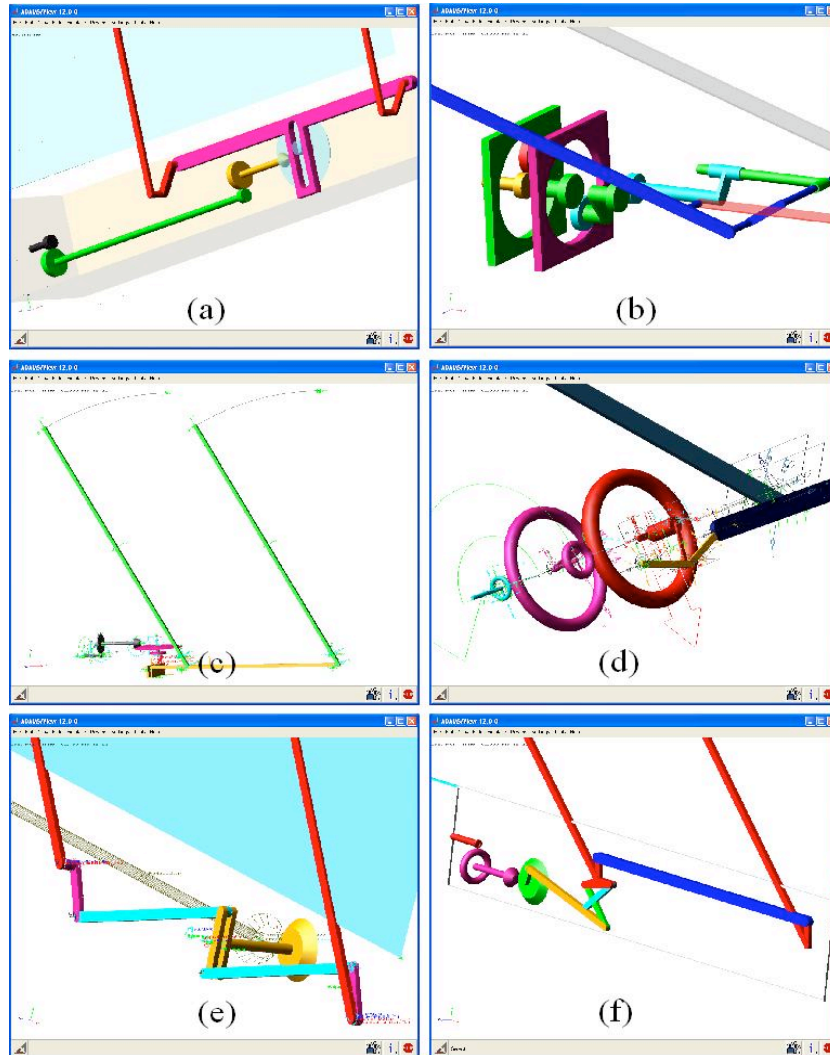


Figure 4. Typical proposed solutions (ADAMS models)

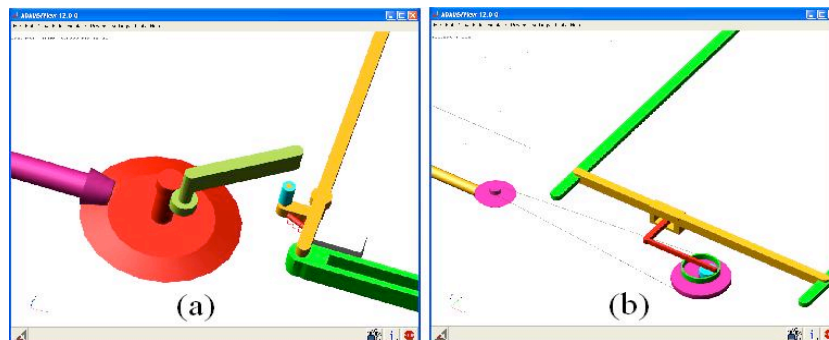


Figure 5. Particular solutions (ADAMS models)

4 CONCLUSION

This work was initially focused on Adams learning but seemed to be appreciated by the students. It gave them the opportunity to express their creativity and to discover the great variety of existing mechanisms. Moreover, it is an interesting experiment from which can be drawn conclusions on human mind and designer behavior.

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