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DEVELOPING SPATIAL IMAGINATION AND ITS APPLICATION IN MECHANICAL ENGINEERING ASSEMBLY DRAWINGS

Abstract

Spatial imagination is a core cognitive competency in engineering education, vital for reading, analyzing, and creating assembly drawings. Learners must reconstruct 3D models from 2D projections. This paper analyzes the theoretical foundations of spatial imagination in reading projections, cross-sections, and identifying assembly relationships. We propose an evaluation criterion system and a developmental process for students based on activity-based learning. A shaft bearing assembly example illustrates the 2D-to-3D conversion process.

Keywords:

spatial imagination, assembly drawing, engineering drawing, mechanical engineering.

1. Introduction

Technical drawings are essential for conveying design, manufacturing, and maintenance data. For assembly drawings, readers must understand the component shapes, positional relationships, and assembly sequences. This demands advanced spatial visualization beyond reading single-part drawings.

Many students master drawing conventions but struggle to visualize 3D assembly structures. Common errors include misidentifying fits, confusing coaxial relationships, or misunderstanding internal features. These issues stem from weak spatial imagination.

Spatial ability directly impacts performance in CAD and mechanical design. In the AI and modern CAD era, spatial imagination remains vital, shifting from basic geometric construction toward structural analysis, feasibility assessment, and logical control of digital models. This necessitates innovative training methods that merge traditional spatial thinking with digital technology.

2. Theoretical Foundations of Spatial Imagination

Spatial imagination is the ability to create, maintain, and transform mental images of objects. In mechanical engineering, it enables converting between 2D projections and 3D models, visualizing internal structures, and reasoning about assembly relationships. This competency synthesizes geometric, technological, and functional thinking.

It consists of four core components:

- **Geometric recognition:** Identifying surfaces, grooves, threads, and holes.
- **Representation conversion:** Moving between 2D projections and 3D models.
- **Mental transformation:** Visualizing objects after rotation, cutting, or assembly.
- **Functional reasoning:** Understanding positioning, force transmission, and operation.

Research (Sorby, Branoff) shows that combining visual models, CAD, and hands-on practice effectively develops these spatial skills.

3. The Role of Spatial Imagination in Assembly Drawings

Spatial imagination helps students identify component shapes and configurations, distinguishing base, rotating, position-ing, and transmission parts within complex, overlapping assemblies.

In cross-sections, it allows learners to visualize cutting planes and internal structures, explaining why components like shafts or bolts are left unhatched. Furthermore, this competency helps predict assembly

sequences and detect design errors—such as component interference or misalignment—making it foundational for mechanical design thinking.

4. Criteria and Methods for Developing Spatial Imagination

To assess spatial imagination in mechanical engineering students, five criteria are applied:

- Converting between 2D projections and 3D models.
- Determining positional and assembly relationships.
- Analyzing internal structures via cross-sections.
- Reasoning about assembly sequences and operating principles.
- Detecting technical design errors.

Assessment combines qualitative activity observation with standardized tests like the Mental Rotation Test (MRT), Purdue Spatial Visualization Test (PSVT), and practical model-construction exercises.

Development rests on three principles: continuous representation conversion, integration with professional CAD/drawing tasks, and visual verification via physical or 3D models.

Learning must be activity-based (observing, analyzing, and simulating) rather than relying on rote memorization. While CAD and 3D simulations provide excellent visual support, over-reliance can hinder independent visualization. Therefore, manual geometric thinking must be balanced with digital technology. Explaining operating principles is particularly vital, as it connects spatial visualization with technical logic by forcing students to trace force transmission and component functions.

5. Process for Training Spatial Imagination

The training process for spatial imagination can be organized into a six-step procedure: (1) Identify the function of each component within the assembly. (2) Determine the base component and the main assembly axis. (3) Perform spatial layering between fixed and moving components. (4) Analyze cross-sections and describe the internal structure. (5) Sketch an exploded view or construct a CAD model. (6) Explain the operating principle and verify assembly feasibility. This process guides students in progressively transitioning from perceptual observation to technical thinking, while simultaneously developing the ability to reconstruct objects in space in a logical and accurate manner. It is important to distinguish spatial imagination from technical design thinking. Spatial imagination primarily concerns the ability to reconstruct and geometrically transform objects in the mind, while technical design thinking encompasses functional analysis, material selection, structural calculation, and manufacturing process optimization. Spatial imagination is an essential cognitive foundation for the formation of technical design thinking.

6. Illustrative Example: Analysis of a Shaft Bearing Assembly

The shaft bearing assembly serves as an example for developing spatial imagination. It consists of a housing, bearings (or bushings), a rotating shaft, retaining caps, and connecting bolts.

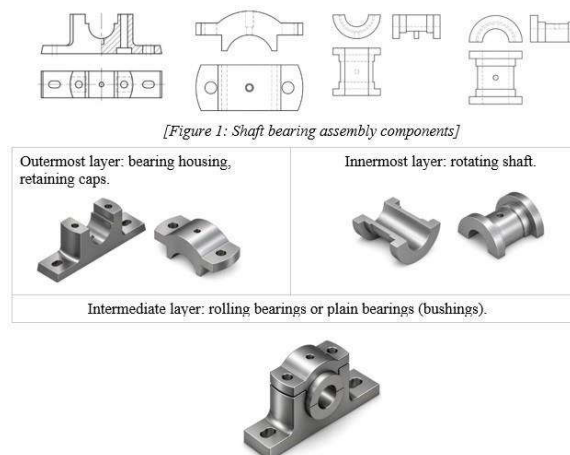


Figure 1 – Shaft bearing assembly components

When reading the front view with a longitudinal cross-section, students must visualize the bearing housing as the outer base component enclosing an interior bore that is coaxial with the rotating shaft. The shaft passes through the bearing and is held in position by retaining caps at both ends. This visualization process requires the learner to simultaneously analyze multiple spatial layers. When reading cross-sections, students must determine which components the cutting plane passes through, which components are hatched in the section view, and which components follow the convention of not being hatched. A correct understanding of the nature of cross-sections helps learners reconstruct the internal structure of the machine assembly. From the assembly drawing, students must also reason out a logical assembly sequence: mount the bearing into the housing, insert the shaft through the bearing, fit the retaining cap, tighten the bolts, and secure the assembly to the machine base. This process illustrates how spatial imagination is directly linked to practical mechanical skills and technological thinking. Common student errors include confusing the bearing housing with the plain bearing (bushing), failing to recognize coaxial relationships, or incorrectly positioning components when constructing a CAD model. This demonstrates that developing spatial imagination requires organizing tasks around actual hands-on manipulation rather than merely studying theory.

7. Conclusion

Spatial imagination plays a foundational role in the technical cognitive activities of mechanical engineering students, particularly in the processes of reading, analyzing, and creating assembly drawings. Beyond purely geometric visualization, this competency is directly related to functional thinking, structural reasoning, the analysis of assembly relationships, and the prediction of machine operating principles. Therefore, developing spatial imagination should be regarded as a core objective in contemporary competency-based mechanical engineering education. This paper has systematized the theoretical foundations of spatial imagination in mechanical engineering drawing, clarifying the role of this competency in reading orthographic projections, cross-sections, and reasoning about assembly structure. On this basis, the study proposes an evaluation criterion system and a training process oriented toward activity-based learning, integrating visual manipulation, CAD modeling, and technical principle analysis. The use of the shaft bearing assembly example demonstrates that the conversion process between two-dimensional representation and three-dimensional models not only supports geometric cognition but also contributes to the formation of technological thinking and technical logic in learners. The research findings indicate that developing spatial imagination cannot be separated from an active learning environment in which students must regularly engage in activities of analysis, prediction, manipulation, and verification using both physical and digital models. This reinforces the position that spatial competency is not a fixed innate ability but can be developed through appropriate instructional design. In the context of digital transformation and the strong development of artificial intelligence in mechanical design, the role of spatial imagination is not diminishing but shifting toward a higher level of thinking, encompassing the capacity to control geometric logic, evaluate assembly feasibility, and analyze the technical validity of digital models. Therefore, modern engineering education must harmoniously integrate traditional spatial thinking with CAD technology, 3D simulation, and intelligent design environments.

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БИОИНСПИРИРОВАННЫЕ ВОЛОКНА КАК ПЕРСПЕКТИВНЫЕ НАПРАВЛЯЮЩИЕ СРЕДЫ В ТЕЛЕКОММУНИКАЦИЯХ

Аннотация

В настоящей статье рассматриваются биоинспирированные оптические волокна - новый класс направляющих сред для телекоммуникационных систем, принципы построения которых заимствованы из биологических структур.

Ключевые слова

биоинспирированные волокна, направляющие среды, оптические волокна, телекоммуникации, фотонные кристаллы, биомиметика, волоконная оптика.

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BIOINSPIRED FIBERS AS PROMISING GUIDING MEDIA IN TELECOMMUNICATIONS

Abstract

This article discusses bioinspired optical fibers, a new class of guiding media for telecommunication systems, the principles of which are borrowed from biological structures.

Keywords:

bioinspired fibers, guiding media, optical fibers, telecommunications, photonic crystals, biomimetics, fiber optics.

1. Введение

Оптические волокна являются основой современных телекоммуникационных сетей, обеспечивая передачу информации на огромные расстояния с высокой пропускной способностью и