Springer Tracts in Mechanical Engineering

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Augmented Reality for Engineering Graphics

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Preface

Engineering is a rapidly evolving field, and engineers must continuously update their skills and knowledge throughout their careers. Engineering education should emphasize the importance of lifelong learning, encouraging engineers to pursue professional development opportunities, engage in continuing education, and stay updated with the latest advancements and best practices in their respective fields.

Engineering education institutions face several challenges in preparing students for the workforce. These challenges include the evolving nature of the industry, the need to keep up with the latest technological advancements, and the lack of collaboration between industry and academia. To overcome these challenges, engineering education institutions must develop and implement programs focusing on experiential learning, interdisciplinary collaboration, industry partnerships, and innovative teaching tools.

Augmented reality (AR) can play a significant role in enhancing the teaching and learning experience for engineering students. AR allows students to visualize and interact with 3D models, simulations, and digital overlays, making understanding complex engineering principles, mechanisms, and structures easier. It bridges the gap between theoretical knowledge and real-world applications. AR provides a hands-on learning experience, allowing students to engage with virtual objects and systems in a simulated environment. They can explore, manipulate, and experiment with virtual components, equipment, and processes, fostering a deeper understanding of engineering principles. AR can simulate experiments, equipment operation, and maintenance procedures, providing a safe and cost-effective way to practice skills and techniques. AR can overlay virtual objects onto the physical environment, enabling students to understand and interact with spatial relationships, design prototypes, and architectural models. It helps students develop critical spatial skills necessary for engineering design and problem-solving. AR can facilitate collaborative learning experiences among engineering students. Multiple users can interact with the same virtual objects simultaneously, enabling group discussions, problem-solving, and teamwork. AR can also support remote collaboration, allowing students to work together on engineering projects regardless of physical location and fostering global collaboration and knowledge sharing. AR can provide context-rich learning experiences by overlaying digital information onto real-world objects and environments. Students can see how engineering concepts and principles are applied in real-world scenarios. AR offers an immersive and interactive learning experience that can increase student motivation and engagement. It can spark curiosity, creativity, and problem-solving skills, encouraging students to explore engineering concepts and applications more deeply.

It's worth noting that while augmented reality offers many benefits, it is not a replacement for traditional teaching methods or practical hands-on experiences. Instead, it complements existing instructional approaches and provides additional tools and resources to enhance engineering education.

In today's rapidly evolving world, where innovation and efficiency are paramount, exploring new avenues for enhancing engineering education and product design processes has become essential. This book addresses these challenges by focusing on the power of augmented reality, visualization techniques, and their practical applications in engineering.

Chapter 1 delves into the significant challenges in engineering education. The defining engineering education and exploring its pivotal role in shaping the future of industries were described. Understanding the labor market requirements is crucial for preparing engineering students to meet the demands of the industry.

Chapter 2 focuses on product design, an integral part of the engineering process. The role of product design and how it aligns with market demands were examined. This chapter provides insights into effective product design strategies, emphasizing user-centered design, innovation, creativity, design for manufacturing, and sustainability.

Chapter 3 explores the visualization of engineering products. Visualization plays a vital role in communicating complex engineering concepts and ideas. We discuss traditional methods of visualization and dive into the world of simulations, augmented reality (AR), virtual reality (VR), and mixed reality (MR). Furthermore, the benefits of visualization technologies in engineering and contemplating the future advancements in this field were outlined.

Chapter 4 presents an in-depth exploration of AR mobile applications in engineering education and industry. AR offers a new dimension of interactive learning and practical implementation, enabling users to overlay virtual objects onto the physical environment. We discuss various use cases and potential applications of AR in engineering.

Lastly, Chap. 5 provides a range of exercises to reinforce the concepts and techniques discussed throughout the book. These exercises offer hands-on opportunities for readers to apply their knowledge and develop practical skills in AR and visualization technologies.

This book will serve as a valuable resource for engineering students, educators, and industry professionals seeking to harness the power of augmented reality and visualization technologies in their learning, design, and problem-solving endeavors.

The book can provide students with a comprehensive understanding of augmented reality technology and its applications in engineering. It can serve as a guide to help them grasp complex engineering concepts more effectively through visualizations. The book can help students develop the necessary skills to design engineering solutions by providing practical examples, case studies, and step-by-step instructions. It can empower them to apply their theoretical knowledge to real-world scenarios and enhance their problem-solving abilities. The book can give students a solid foundation in augmented reality technology and its applications, making them more attractive to potential employers.

The book can serve as a resource for industry professionals seeking to expand their knowledge and stay updated on the latest advancements in AR within the engineering domain. It can provide insights into industry best practices, case studies, and practical implementation strategies. The book can inspire professionals to explore and adopt AR solutions in their workflows, leading to increased innovation, improved efficiency, and enhanced productivity. The book can guide industry professionals in integrating augmented reality technologies with existing engineering systems and processes. This knowledge can help them leverage the benefits of AR without disrupting established workflows, ensuring a smooth transition and implementation.

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Chapter 1
Major Challenges in Engineering Education

1.1 Definition of Engineering Education

Engineering is a broad discipline that applies scientific and mathematical principles to design, develop, build, and maintain structures, machines, systems, and processes. It involves the application of technical knowledge and skills to solve complex problems and create innovative solutions for various fields and industries.

Engineers use their expertise to bridge the gap between scientific theories and practical applications. They apply scientific principles, such as physics and mathematics, along with their understanding of materials, mechanics, and systems to design, analyze, and improve technological systems.

Engineering encompasses various specialties or fields, including civil engineering, mechanical engineering, electrical engineering, chemical engineering, aerospace engineering, computer engineering, and many more (Fig. 1.1). Each field focuses on specific areas and applications. Still, they all share a common goal of designing and creating solutions that meet specific needs or objectives.

Engineers are involved in all project stages, from research and planning to design, construction, testing, production, and maintenance. They work collaboratively with professionals from other disciplines and industries to ensure their designs are safe, efficient, and cost-effective.

The impact of engineering can be seen in numerous aspects of everyday life, from the construction of buildings and infrastructure to developing transportation systems, communication networks, medical devices, renewable energy technologies, and much more. Engineers play a crucial role in driving technological advancements and shaping our world.

Engineering education refers to the process of acquiring knowledge, skills, and competencies in the various fields of engineering. It involves formal study and training that prepares individuals to become professional engineers. Engineering education typically occurs at universities, colleges, or technical institutions and follows a structured curriculum.

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Aerospace Engineering	•deals with the design, construction, and testing of aircraft and spacecraft.
Chemical Engineering	•deals with the application of chemistry, physics, and mathematics to solve problems related to the production of chemicals, fuel, drugs, and other products.
Civil Engineering	•involves the design, construction, and maintenance of infrastructure such as roads, bridges, buildings, and water supply systems.
Computer Engineering:	•focuses on the design and development of computer hardware, software, and networks.
Electrical Engineering:	•deals with the study and application of electricity, electronics, and electromagnetism.
Environmental Engineering:	•involves the application of engineering principles to improve the natural environment, including air, water, and land.
Industrial Engineering	•focuses on improving the efficiency and productivity of industrial processes, such as manufacturing and logistics.
Materials Engineering	•deals with the study and development of materials, including metals, ceramics, polymers, and composites.
Mechanical Engineering	•involves the design, development, production, and maintenance of mechanical systems, such as engines, machinery, and vehicles.
Petroleum Engineering	•deals with the exploration, production, and distribution of oil and gas resources.
Systems Engineering	•focuses on the design and integration of complex systems, such as transportation systems, communication networks, and aerospace systems.

Fig. 1.1 Engineering fields (in alphabetical order)

The main objective of engineering education is to provide students with a solid foundation in mathematics, science, and engineering principles. Students learn theoretical concepts and practical applications through lectures, laboratory work, and hands-on projects. The curriculum typically includes courses in mathematics, physics, chemistry, computer science, and specialized engineering disciplines based on the student's chosen field.

Engineering education also emphasizes problem-solving skills, critical thinking, and design principles. Students are encouraged to apply their knowledge to solve complex engineering problems and develop innovative solutions. They may also learn about project management, teamwork, communication skills, and ethical considerations in engineering practice.

In addition to classroom learning, engineering education often includes internships, co-op programs, or industry collaborations, allowing students to gain practical experience and apply their skills in real-world settings. These opportunities enhance students' understanding of engineering practice and provide valuable exposure to professional work environments.

Ultimately, engineering education aims to produce competent and well-rounded engineers capable of designing, analyzing, and implementing solutions to address societal needs and challenges in various engineering fields.

1.2 The Role of Engineering Education

Engineering education plays a vital role in shaping the modern world by providing individuals with the knowledge and skills needed to solve complex problems, develop innovative technologies, and improve the quality of life of people worldwide. A well-trained engineering workforce can improve innovation and technology development, thus increasing competitiveness in the global market [1]. In addition, engineering education is critical for developing new products, processes, and services necessary for sustainable economic growth [2].

Engineering education faces several challenges (Fig. 1.2) that must be addressed to prepare graduates for the future. The engineering education system must keep up with the latest technological advancements, promote industry-academia collaboration, provide quality education, promote diversity and inclusion, and provide opportunities for lifelong learning to produce skilled and competent engineers who can meet the demands of the industry.

The engineering curriculum should be updated regularly to reflect the latest technological advancements. The engineering education system must ensure that graduates possess the skills and knowledge to face the challenges of the ever-evolving technological landscape [3]. It requires the development of new courses, the integration of emerging technologies into the curriculum, and the identification of new areas of research.

The lack of collaboration between industry and academia is a significant challenge in engineering education. The industry needs skilled professionals to remain

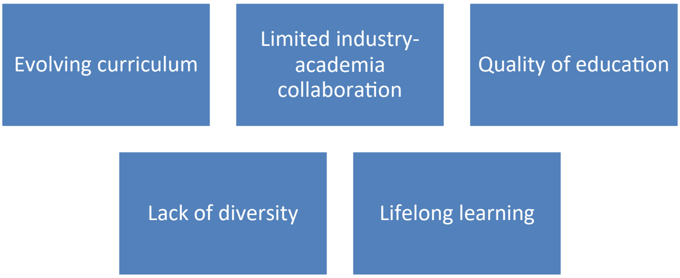

Fig. 1.2 Challenges for engineering education

competitive, and academia needs to stay up-to-date with the latest industry trends and technologies. Collaboration between these two sectors can help bridge the gap and provide students with practical knowledge and hands-on experience [4].

Quality education is critical to the success of engineering students [5]. However, many institutions struggle to provide students with quality education due to factors such as lack of funding, inadequate infrastructure, and lack of qualified faculty. These factors can have a detrimental effect on the quality of education provided to students. As a result, graduates may not possess the necessary skills to excel in the industry.

The engineering field lacks diversity [5], with a low representation of women and underrepresented minorities. This lack of diversity limits the perspectives and ideas that students can bring to the table, hindering the development of innovative solutions to engineering problems. The engineering education system must take steps to address this challenge by promoting diversity and inclusion and providing equal opportunities for all students.

The engineering field constantly evolves, and engineers must continually improve their skills and knowledge to remain competitive. The engineering education system must incorporate lifelong learning opportunities [6] into the curriculum to ensure that graduates are prepared to meet the demands of the ever-changing technological landscape.

1.3 Labor Market Requirements

In today's rapidly changing technological landscape, engineering graduates face increasing demands from the labor market. Industry requires skilled professionals with the necessary knowledge and skills to face the challenges of the modern world. To meet the demands of the labor market, engineering graduates need to possess several essential skills. These skills include but are not limited to technical knowledge; problem-solving skills; communication skills; collaboration skills.

Engineering graduates must have a strong foundation in technical knowledge related to their field of study. It includes knowledge of the latest technologies and tools used in the industry.

Engineering graduates must possess excellent problem-solving skills to tackle the challenges faced by the industry. They must be able to identify problems, analyze data, and develop innovative solutions to complex problems.

Communication skills are critical for engineering graduates, as they need to be able to communicate effectively with team members, clients, and stakeholders. They must be able to present their ideas and findings clearly and concisely.

Engineering graduates must be able to work effectively in teams, collaborate with colleagues, and build strong working relationships.

Regarding technical skills in mechanical engineering, which play a vital role in various industries, some key areas of labor market demands are described below (Fig. 1.3).

The advent of advanced manufacturing techniques, such as additive manufacturing, computer numerical control (CNC) machining, and robotic automation, has significantly influenced the labor market demands for mechanical engineers. There is a growing need for engineers who can design and optimize manufacturing processes, work with robotic systems, and integrate automation solutions for increased productivity and efficiency.

The global focus on sustainability and environmental conservation has led to an increased demand for mechanical engineers who can develop and implement sustainable solutions. It includes designing energy-efficient systems, developing renewable energy technologies, optimizing resource utilization, and ensuring environmental compliance in manufacturing processes.

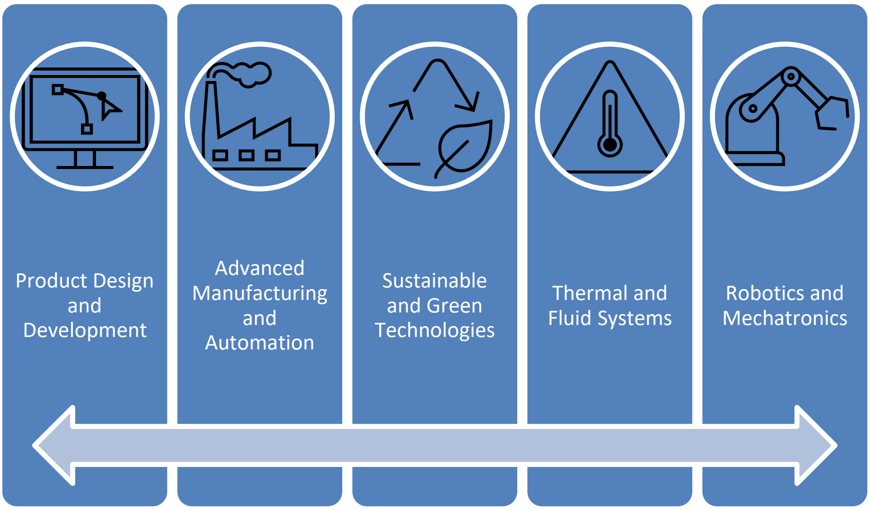

Fig. 1.3 Key areas of labor market demands

Mechanical engineers with expertise in thermal and fluid systems are highly sought after in industries such as HVAC (heating, ventilation, and air conditioning), automotive, aerospace, and energy.

Integrating robotics and mechatronics into various industries, including manufacturing, healthcare, and transportation, has created a demand for mechanical engineers with expertise in these areas. The labor market highly values the ability to design and control robotic systems, develop intelligent machines, and integrate mechanical and electronic components.

Mechanical engineers play a crucial role in product design and development. There is a demand for graduates who can conceptualize, design, and prototype innovative products, conduct feasibility studies, and apply engineering principles to ensure the final product's functionality, reliability, and manufacturability.

In conclusion, the labor market demands for engineering graduates are constantly evolving, and engineering education institutions need to prepare students to meet these demands by providing them with the necessary knowledge and skills. It requires a collaborative effort between the industry and academia to bridge the gap and ensure that engineering graduates possess the skills required to succeed in the workforce.

1.4 New Technologies in Engineering Education

Engineering education has long relied on traditional teaching methods such as lectures, textbooks, and hands-on projects. Many generations of engineers have clearly proven that these methods are effective. However, with the advent of new technologies such as augmented reality (AR) [7], mixed reality (MR) [8], and virtual reality (VR) [9], there is an opportunity to change the way engineering education is conducted and improve its effectiveness by increasing student engagement and presenting complex issues more clearly.

The AR and VR market is expected to experience significant growth in the coming years. With technological advancements and increasing adoption across various industries, the market is projected to expand steadily. According to forecasts, the AR and VR market is estimated to continue its upward trajectory, with a compound annual growth rate (CAGR) of 48.8% from 2020 to 2025, with estimated revenue reaching 161.1 billion by 2025 [10].

These technologies belong to the reality-virtuality continuum [11] and are increasingly used for entertainment and as a tool that supports education. The reality-virtuality continuum is a concept that represents the spectrum of experiences ranging from the physical reality we perceive to the virtual reality that is entirely computer-generated.

At one end of the continuum is a physical reality, which refers to the real-world environment we perceive through our senses. It includes the tangible objects, people, and events that exist in the physical world. In this state, our experiences are entirely grounded in the real world, and our senses provide us with direct and unmediated information.

Moving along the continuum, we encounter augmented reality (AR), which blends virtual elements with the physical environment. AR technology has significantly impacted engineering education, improving students' understanding of engineering concepts and enhancing their problem-solving skills. Engineering education institutions embrace AR technology to improve teaching methodologies and prepare students for the labor market. AR overlays computer-generated sensory inputs, such as visuals, sounds, or haptic feedback, onto our real-world perception. This technology enhances our perception and understanding of the physical environment by providing additional information or digital content that augments our senses. Examples of AR applications include smartphone apps that overlay virtual information on real-time camera views.

Further, along the continuum, we reach mixed reality (MR), also known as hybrid reality. MR merges virtual objects with the physical environment to allow users to interact with both. Unlike AR, which overlays virtual content onto the physical world, MR seamlessly integrates virtual and real-world elements, creating an environment where physical and digital objects coexist and interact in real time. This technology enables users to perceive and manipulate virtual objects as part of the physical world, leading to immersive and interactive experiences.

Finally, at the far end of the continuum is virtual reality (VR), which completely replaces the physical world with a computer-generated virtual environment. VR technology uses head-mounted displays (HMDs) and other sensory devices to create an immersive and interactive digital world that users can explore and experience by users. In VR, users are fully immersed in a computer-generated environment, and their physical surroundings are blocked out, leading to a higher sense of presence and immersion.

The reality-virtuality continuum provides a framework for understanding the different levels of immersion and interaction between the real and virtual worlds. It illustrates how technology can augment or modify our perception of reality, from enhancing our real-world experiences with virtual content (AR) to fully immersing us in virtual environments (VR). This continuum has significant implications for various fields, including entertainment, education, training, simulation, and communication, as it offers a range of possibilities to create diverse and engaging experiences.

One of the key benefits of using AR, MR, and VR in engineering education is that they allow students to visualize and interact with complex concepts more tangibly. For example, using AR technology, students can view and manipulate 3D models of complex engineering structures and systems, which can help them better understand how they work. MR technology can enable students to visualize the integration of virtual and physical components in real time, providing a more comprehensive understanding of complex engineering concepts.

Another benefit of using AR, MR, and VR in engineering education is that they can provide a more immersive and interactive learning experience. It can increase student engagement and motivation, improving learning outcomes [12]. For example, VR technology can simulate real-world scenarios, allowing students to practice and apply their engineering skills in a safe and controlled environment [13]. Furthermore, AR, MR, and VR technologies can promote collaboration and interdisciplinary learning [14]. Students can engage in virtual teamwork and co-create solutions to engineering challenges, regardless of their physical location. These technologies also facilitate access to global expertise and resources, allowing students to learn from industry experts and interact with virtual simulations of real-world engineering projects. Collaborative learning experiences enhance problem-solving and communication skills, expose students to diverse perspectives, and promote innovation.

However, implementing AR, MR, and VR in engineering education also presents challenges [15]. One challenge is the cost of developing and implementing immersive content. Creating high-quality immersive content requires specialized equipment and expertise, which can be expensive. However, in recent years, the cost of AR/VR/MR devices has dropped significantly and is no longer such an obstacle as it used to be [16]. Another challenge is the need for specialized training for instructors and students to use these technologies effectively.

Despite these challenges, there is growing evidence of the effectiveness of AR, MR, and VR in engineering education. Studies have shown that AR technology improves student engagement, motivation, and learning outcomes [17], indicating the potential of AR technology to improve engineering education. Similarly, studies found that using VR technology improved engineering students' learning outcomes and participation in the classroom [18].

Regarding MR technology, the study found that with the support of MR technology, students' abilities in geometric analysis and creativity were significantly improved, especially in their model visualization ability [19].

Immersive technologies such as AR, MR, and VR have the potential to revolutionize engineering education, making it more effective in various ways. These cutting-edge technologies give students a tangible understanding of complex engineering concepts, increase their engagement and motivation, and offer invaluable hands-on experience. Despite potential challenges in implementation, the overwhelming evidence suggests that immersive technologies present effective solutions to the primary obstacles faced by engineering education institutions.

By incorporating immersive technologies into their curricula, engineering education institutions can improve traditional teaching methods and offer hands-on experiential learning opportunities. Moreover, these technologies significantly enhance student engagement and motivation. The findings clearly indicate the need for engineering education institutions to consider embracing AR, MR, and VR seriously. By doing so, these institutions can unlock new dimensions of learning, empower students with practical knowledge, foster creativity and innovation, and ultimately better equip graduates for the dynamic and evolving landscape of the engineering field.

In summary, immersive technologies hold great potential for revolutionizing engineering education. They offer a more tangible understanding of complex concepts, enhance student engagement and motivation, and provide valuable hands-on experience. By embracing these technologies, engineering education institutions can create a transformative learning environment that prepares students to excel in the challenges and opportunities of the modern engineering industry. Therefore, engineering education institutions must adopt immersive technologies as a means to improve teaching quality and better equip students for the changing demands of the labor market.

1.5 Further Development of Engineering Education

Engineering education is continuously evolving to meet the changing demands of society and industry. As engineering becomes more complex and interconnected, there is a growing emphasis on interdisciplinary education. Integrating knowledge and skills from multiple engineering disciplines and incorporating principles from other fields like computer science, biology, and social sciences can better prepare engineers to address real-world problems that require a multidisciplinary approach.

Project-based learning approaches are gaining popularity in engineering education. These approaches involve students working on hands-on, open-ended projects that simulate real-world engineering challenges. This approach fosters critical thinking, problem-solving skills, teamwork, and communication abilities, as students apply their knowledge to solve complex problems.

Experiential learning methods, such as internships, co-op programs, and industry collaborations, provide students with practical, real-world experience. These opportunities expose students to the challenges and intricacies of engineering practice, allowing them to apply their knowledge in professional settings and develop a deeper understanding of industry expectations.

In addition to technical knowledge, engineering education places greater importance on developing soft skills. Effective communication, teamwork, leadership, ethical considerations, and cultural competence are crucial for engineers collaborating with diverse teams, managing projects, and engaging with stakeholders. Integrating these skills into the engineering curriculum helps produce well-rounded professionals.

Engineering education must keep pace with emerging technologies. Integrating topics like artificial intelligence, virtual and augmented reality, robotics, data science, and sustainable design into the curriculum helps students understand and leverage these technologies in their future engineering careers.

Efforts to increase diversity and inclusion in engineering education are crucial. Encouraging participation from underrepresented groups, promoting equal opportunities, and creating inclusive learning environments can help address the existing gender and diversity gaps in engineering and foster a more diverse and inclusive engineering workforce.

By embracing these developments and adapting to the changing needs of society, engineering education can produce highly skilled, adaptable, and socially conscious engineers who are equipped to tackle the complex challenges of the future.

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Chapter 2
Product Design

2.1 The Role of Product Design

Product design refers to creating and developing new products or improving existing ones to meet specific objectives and user needs. Product design addresses various aspects such as aesthetics, functionality, usability, ergonomics, materials, manufacturing processes, cost-effectiveness, and sustainability. Design engineers work on translating ideas and concepts into tangible products by considering factors like market research, user feedback, technical feasibility, and business objectives.

Product design typically involves a series of stages, including ideation, conceptualization, prototyping, testing, and final production. It requires a multidisciplinary approach involving collaboration among designers, engineers, marketers, and other stakeholders, to ensure that the resulting product aligns with the intended goals and satisfies user requirements.

An effective product design process strives to create products that are visually appealing, intuitive to use, reliable, and capable of fulfilling the desired functions. It combines creativity, problem-solving skills, and a deep understanding of user behaviors and preferences to deliver innovative solutions that enhance the overall user experience and create a competitive advantage in the market.

Product design involves integrating knowledge from multiple disciplines, such as engineering, design, and marketing [1]. In the rapidly evolving landscape of technology and consumer preferences, the importance of product design cannot be overstated. It bridges engineering education and market demands, combining engineering principles with user-centered design [2] to create innovative and appealing products. The entire process, from identifying user needs to prototyping, testing, and manufacturing, is included. A well-designed product not only fulfills functional requirements but also but should also satisfy consumers' psychological needs [3]. Product design plays a multifaceted and indispensable role in meeting market demands and driving the success of businesses (Fig. 2.1).

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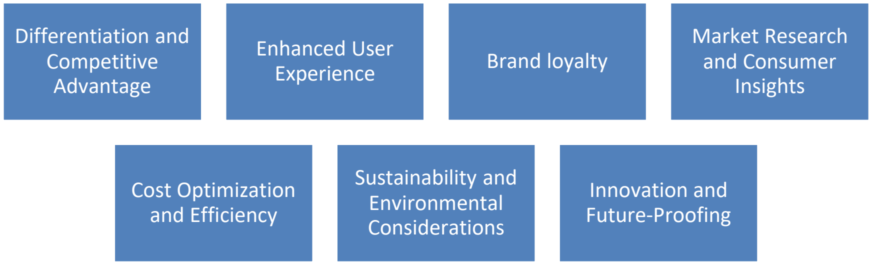

Fig. 2.1 Market demands

In a crowded market, product design is a powerful tool for differentiation. An innovative and well-designed product can capture consumers' attention, generate brand recognition, and establish a competitive advantage in the market [4].

Product design strongly emphasizes understanding user needs and preferences [3]. An intuitive interface, ergonomic design, and seamless interaction contribute to increased customer satisfaction, repeat purchases, and positive recommendations.

Successful product design aims to create an emotional connection between the user and the product. This emotional connection fosters brand loyalty [5], encouraging consistently choosing a particular brand over its competitors.

Product design is deeply intertwined with market research and consumer insight. Designers conduct thorough research to understand market trends, consumer behaviors, and emerging needs. This research-driven approach minimizes the risk of developing products that do not resonate with the target audience [6].

Efficient product design considers manufacturing processes, materials, and production costs. By considering those factors, engineers and designers can optimize the production process, reduce costs, and improve efficiency [7].

Product design plays a pivotal role in addressing environmental concerns and sustainability challenges. Designers increasingly incorporate eco-friendly materials, energy-efficient technologies, and recyclable components into their products. By considering the entire lifecycle of a product, from sourcing materials to disposal, designers can minimize the environmental impact and promote sustainable consumption practices [8].

Product design is a driving force behind innovation. It encourages engineers and designers to think creatively, push boundaries, and develop cutting-edge solutions by embracing emerging technologies, exploring novel design approaches, and anticipating future trends [9].

2.2 Understanding Market Demands

Ever-changing consumer preferences, technological advancements, and societal trends drive market demands. Market demands encompass consumers' and stakeholders' needs, desires, preferences, and expectations within a specific industry or target market. The key points to understanding market demands are the following: identifying customer needs; analyzing competitor offerings; adapting to technological advancements; incorporating feedback and iteration; consumer-centric design thinking.

Effective product design starts with deeply understanding customer needs [10]. Companies can gain insight into their target customers' pain points, challenges, and aspirations by conducting market research, surveys, focus groups, and interviews. This knowledge helps to develop products that directly address those needs, providing valuable solutions and increasing the likelihood of customer adoption.

Understanding market demands requires a comprehensive analysis of competitor offerings. By studying the strengths and weaknesses of existing products on the market, businesses can identify gaps or areas for improvement [11]. This analysis informs product design decisions, allowing companies to create products that differentiate themselves and offer unique value propositions to customers.

Advancements in technology often lead to new opportunities and disrupt existing markets. By understanding the impact of emerging technologies, businesses can adapt their product designs to leverage these advancements. This adaptability ensures that the products remain competitive, innovative, and aligned with the customers' evolving needs.

Understanding market demands is an ongoing process that involves actively seeking and incorporating customer feedback [12]. It allows businesses to refine their product designs based on real-world insights, improve customer satisfaction, and address shortcomings.

Market demands are best understood through the lens of consumer-centric design thinking. This approach places the end user at the center of the design process, focussing on empathy, ideation, prototyping, and testing [13]. By adopting design thinking methodologies, companies can gain a deep understanding of user needs, pain points, and aspirations, enabling them to create products that truly resonate with customers.

2.3 User-Centered Design

One of the fundamental principles of product design is user-centeredness. By placing the end user at the core of the design process, engineers and designers gain valuable insights into their needs, desires, and pain points. This user-centric approach ensures that the final product meets or exceeds user expectations, increasing customer satisfaction and brand loyalty. User-centered design (UCD) is a fundamental approach in product design that prioritizes the needs, goals, and experiences of the end-users [2]. It emphasizes the importance of understanding users' behaviors, preferences, and expectations throughout the design process.

User-centered design recognizes that user needs and preferences evolve over time. Therefore, it promotes a culture of continuous improvement and adaptation. Designers actively seek user feedback, monitor usage patterns, and leverage analytics to gain insights into user behaviors and changing needs. This information helps make iterative improvements, add new features, or adapt the product to better serve users as their requirements change.

2.4 Innovation and Creativity

Product design encourages innovation and creativity by challenging engineers to think beyond conventional solutions. It fosters a culture of experimentation and iteration, where engineers can explore new materials, technologies, and design concepts. By encouraging interdisciplinary collaboration, engineering education should equip students with the following skills (Fig. 2.2) to generate new breakthrough ideas [14].

Innovation and creativity are essential for effective problem-solving. Product designers are constantly faced with challenges that range from improving existing products to developing entirely new solutions. By applying innovative thinking and creative approaches, designers can generate breakthrough ideas and novel solutions to address these challenges. Problem-solving is the core of engineering practice [15].

Innovation and creativity are integral components of design thinking methodologies. By encouraging diverse perspectives, collaborative brainstorming, and experimentation, design thinking fosters a culture of innovation and creativity. It empowers designers to challenge assumptions, explore unconventional ideas, and iterate on designs based on user feedback, leading to more refined and impactful solutions.

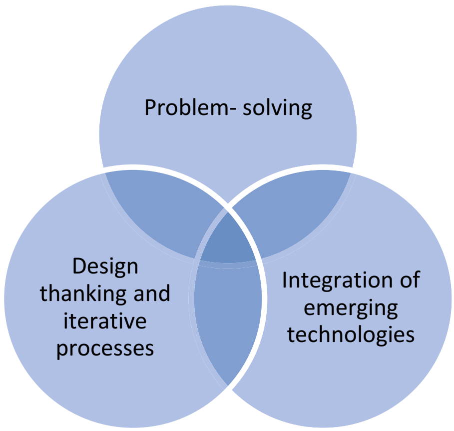

Fig. 2.2 Essential components for innovation and creativity

Innovation and creativity drive the integration of emerging technologies into product design. As new technologies emerge, such as artificial intelligence, virtual reality [16], or the Internet of Things (IoT) [17], designers can take advantage of these advances to create innovative, cutting-edge products. By envisioning novel applications and combinations of technologies, designers can pioneer new product categories or disrupt existing markets. Engineering students must learn about those technologies during their education.

2.5 Design for Manufacturing

Design for Manufacturing (DFM) is a critical aspect of product design that focuses on optimizing the design of a product to ensure efficient and cost-effective manufacturing processes [18, 19]. DFM aims to streamline production, reduce manufacturing costs, improve product quality, and minimize time-to-market. It is crucial that in the course of engineering education, students become familiar with this method because it:

- simplifies manufacturing processes by considering the capabilities and limitations of manufacturing technologies early in the design phase;
- optimizes production and minimizes material waste based on material selection and standardization;
- focuses on designing products for easy assembly, reducing complexity, and lowering assembly costs;
- minimizes manufacturing defects and improves product quality based on the tolerance analysis and optimization of the design;
- designs products with cost-effective manufacturing, considering tooling, labor, and material costs;
- designing for testability and quality improves product reliability and customer satisfaction;
- promotes collaboration between designers and manufacturers to optimize manufacturing efficiency and smoothly transition from design to production.

2.6 Sustainability

Sustainability is a key factor driving market demands in today's environmentally conscious society. Product design is essential in creating sustainable solutions, considering such factors as material selection, energy efficiency, recyclability, and end-of-life disposal. By integrating sustainable design principles, engineers can develop products that meet the values and expectations of environmentally conscious consumers. The importance of sustainability in product design is highlighted by the following issues: reduction of environmental impact; life cycle assessment; circular economy principles; renewable energy; supply chain consideration.

Addressing sustainability involves minimizing the environmental impact of products throughout their lifecycle. Designers can use various strategies, such as using environmentally friendly materials, reducing energy consumption, optimizing packaging to minimize waste, and considering the end-of-life disposal of the product [20].

Sustainable product design involves performing a life cycle assessment (LCA) [21] to assess the environmental impact of a product from the extraction of raw materials to disposal. By considering the entire life cycle, including production, transportation, use, and end-of-life, designers can identify areas for improvement and make informed decisions to reduce the overall environmental footprint. LCA enables designers to prioritize sustainable choices and optimize resource utilization.

Designing for sustainability embraces the principles of the circular economy, which aims to minimize waste and maximize resource efficiency. By incorporating product durability, reparability, and recyclability concepts, designers can extend the product's lifespan and reduce the need for resource-intensive manufacturing. Designing products that can be easily disassembled and recycled promotes the recovery of valuable materials, reducing waste and minimizing environmental degradation [22].

Sustainable product design involves considering the integration of renewable energy sources. Designers can explore opportunities to incorporate solar panels, energy harvesting mechanisms, or energy-efficient technologies into the product design. By utilizing renewable energy, products can reduce reliance on traditional energy sources and lower carbon emissions [23].

Sustainable product design involves evaluating and optimizing the entire supply chain. Designers collaborate with suppliers to ensure responsible materials sourcing, ethical labor practices, and adherence to environmental regulations. By partnering with suppliers committed to sustainability, designers can reduce the ecological and social impact of the product throughout its supply chain [24].

Product design is a powerful tool that connects engineering education with market demands. It blends technical expertise with creativity, user-centeredness, and sustainability to create products that meet the needs of today's consumers. By embracing product design principles, engineering education equips students with the skills and mindset necessary to tackle real-world challenges, drive innovation, and shape a future where technology and human needs are seamlessly integrated.

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Chapter 3
Visualization of Engineering Products

3.1 Role of Visualization of Engineering Products

Visualization of engineering products plays a crucial role in the design and development process. It allows engineers and designers to effectively communicate ideas, evaluate designs, identify potential issues, and make informed decisions before the physical production phase begins.

In recent years, technological advancements have brought about new and exciting ways to visualize engineering products through augmented reality (AR), virtual reality (VR), and mixed reality (MR) applications. As mentioned in previous chapters, it is crucial that in the course of engineering education, future engineers become familiar with these technologies and the possibility of their integration into professional work. However, in engineering education, the student should also become familiar with more traditional visualization methods, which are still an essential part of the product design and production process. This chapter will describe different visualization methods, starting from traditional methods through simulation methods to AR/VR/MR.

3.2 Traditional Methods of Visualization of Engineering Products

Despite the advancements in virtual reality, augmented reality, and simulation tools, sketching, 2D drawings, and CAD remain prevalent and vital in engineering product development. They provide the groundwork for effective communication, collaboration, and documentation throughout the product lifecycle.

Sketching is a fundamental visualization technique engineers and designers use to convey their ideas on paper or digital tools quickly. It allows for rapid exploration of concepts, roughing out designs, and visualizing basic shapes and forms.

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Detailed 2D drawings provide precise geometric information about the product. These drawings typically include orthographic projections, isometric views, and sections that showcase dimensions, tolerances, and annotations. They are commonly used for manufacturing, assembly, and documentation purposes.

CAD software enables engineers to create digital models of their designs in three dimensions. CAD models are highly accurate and can be easily manipulated, modified, and analyzed. They allow for comprehensive product visualization from different angles, including exploded views, cross-sections, and animations.

3.3 Simulations in the Visualization of Engineering Products

By employing computational models, engineers and designers can simulate the performance of engineering products under various operating conditions. Simulation of designed products and complex systems provides additional information to engineers, enabling adjustments to be made at the design stage. Simulation methods are a broad topic, which includes, among others, the following ones.

Finite Element Analysis (FEA) is a numerical simulation technique used to analyze the structural behavior of products under various loading conditions. It visualizes stress, strain, deformation, and other critical factors by representing them as color-coded maps or contour plots. FEA allows engineers to optimize designs, identify weak points, and ensure the product's reliability [1].

Computational Fluid Dynamics (CFD) simulations are employed to analyze fluid flow and heat transfer in engineering products. Visualization techniques, such as streamlines, velocity vectors, and temperature contours, help engineers understand the behavior of fluids within the product, optimize thermal management, and improve performance [2].

Motion Simulation software enables engineers to analyze the kinematics and dynamics of moving parts within a product. By visualizing the motion of mechanisms, engineers can identify interference, collision, or any undesired behavior. Animations and graphs help assess factors like velocities, accelerations, forces, and torques [3].

3.4 Augmented Reality

AR allows engineers to project virtual models, schematics, and data onto physical objects, providing real-time visual feedback and aiding in design, assembly, and maintenance processes. AR solutions can be based on smartphones, tablets [4], or smart glasses so that users can see real worlds enhanced (augmented) by virtual content. It allows users to perform activities (interactions) in the real world and to manage virtual content [5]:

- Design Review and Evaluation [6]: AR allows engineers to visualize and assess product designs in real-world contexts. By superimposing digital 3D models onto physical objects or environments, engineers can evaluate the product's form, fit, and function early.
- Assembly and Maintenance Guidance [7]: AR can provide step-by-step instructions and guidance during assembly, maintenance, or repair processes. By overlaying visual cues, animations, and text onto physical objects, AR enables workers to follow precise instructions and locate components accurately. It reduces errors, improves efficiency, and enhances training processes by providing real-time visual aids.
- Contextual Visualization [8]: AR provides a unique advantage by allowing engineers to visualize products in their intended environments [6] or specific working conditions. Mechanical engineers can simulate the behavior of a machine in an industrial setting, considering factors like space constraints or safety considerations.
- Marketing and Sales Presentations. AR enables immersive and interactive marketing and sales experiences for engineering products. Companies can use AR applications to showcase products to potential customers, allowing them to visualize the product in their environment.
- Visualization of Hidden Components [9]: AR can reveal internal components or structures not directly visible in physical prototypes. Engineers can inspect internal features, such as wiring, piping, or complex assemblies, by overlaying virtual cross-sections or cutaways onto physical objects. This visualization aids in detecting design flaws, optimizing internal layouts, and facilitating maintenance or troubleshooting activities.
- Training and Simulation: AR can be used for training operators or simulating complex scenarios. By overlaying virtual information onto physical training objects, such as control panels or machinery, AR provides a hands-on learning experience. Operators can practice their skills, learn procedures, and gain confidence in operating equipment without the risks associated with real-world operations. AR simulations can mimic realistic conditions, such as emergencies or abnormal operating conditions, improving operator preparedness and safety.

3.5 Virtual Reality

VR enables users to interact with 3D models of products, exploring their functionality, ergonomics, and aesthetics. In recent years, engineering applications of VR have been widely described in the literature. The most frequently mentioned VR applications in this context are:

- Immersive Design Reviews [10]: VR enables engineers to immerse themselves in a virtual representation of the product. They can explore and interact with the digital model at a scale that provides a realistic sense of size and proportion. The immersive experience enables details examination, and moving around the virtual prototype improves the evaluation of design aesthetics, ergonomics, and spatial relationships.

- Interactive Assembly and Disassembly [11]: VR can assist in assembly and disassembly processes by providing step-by-step guidance and visual aids. Engineers can visualize and practice assembling complex components using virtual representations, ensuring proper fit and alignment.
- Training and Simulation [12]: VR offers a safe and controlled environment for training operators and simulating complex scenarios. Engineers can create virtual simulations to train operators on equipment operation, maintenance procedures, or emergencies. Users can practice their skills, interact with virtual equipment, and gain confidence in a realistic but risk-free environment.
- Ergonomics and Human Factors Analysis [13]: VR is valuable for evaluating engineering products' ergonomics and human factors. Engineers can simulate human interactions with virtual prototypes to assess reachability, visibility, and accessibility. By virtually placing users in different scenarios, VR can help identify potential issues and optimize the design for enhanced usability and user experience.
- Marketing and Sales Presentations [14]: VR provides a compelling medium for marketing and sales presentations of engineering products. Companies can create virtual showrooms or experiences that allow potential customers to explore and interact with virtual prototypes.

3.6 Mixed Reality

MR is particularly useful for tasks that require spatial understanding and manipulation of complex engineering products. MR headsets equipped with spatial mapping and hand-tracking capabilities can allow engineers to place, manipulate, and simulate the behavior of virtual components within a real-world context. Applications of MR in engineering visualization include:

- Real-Time Data Overlay [15]: MR allows engineers to overlay real-time data onto digital models, providing valuable insights during design and analysis. For example, sensors or monitoring systems can capture live data such as temperature, pressure, or stress, which can then be visualized and superimposed onto the corresponding areas of the virtual model. This real-time data overlay enhances the understanding of product performance, facilitates data-driven decision-making, and supports predictive maintenance and optimization efforts.
- Interactive Design Reviews [15]: MR facilitates collaborative design reviews by enabling multiple stakeholders to visualize and interact with digital models simultaneously. Engineers, clients, and other stakeholders can wear MR headsets and view the exact virtual representation, allowing for real-time discussions, annotations, and design modifications. This interactive design review process fosters better communication, consensus building, and accelerated decision-making, ultimately leading to improved design outcomes.

- Dynamic Prototyping and Simulation [16]: MR enables engineers to prototype and simulate the behavior of engineering products in real time. By integrating virtual models with physical objects, engineers can physically interact with the virtual components and observe their dynamic responses. This capability is particularly valuable for evaluating mechanisms, kinematics, and dynamic simulations. Engineers can assess the movements, forces, and constraints of virtual prototypes, leading to enhanced understanding, optimization, and refinement of designs.
- Remote Collaboration and Assistance [17]: MR facilitates remote collaboration among geographically dispersed teams. Engineers can share their MR experiences with colleagues and stakeholders, allowing them to view and interact with virtual models remotely. This capability enables real-time collaboration, design reviews, and troubleshooting sessions regardless of physical location. Additionally, MR can provide remote assistance by overlaying virtual instructions or annotations onto physical objects, guiding technicians or operators through complex procedures.
- Training and Skill Development [18, 19]: MR offers immersive and interactive engineering product operations and maintenance training environments. Users can visualize virtual equipment, interact with virtual controls, and practice simulated procedures in a realistic context. MR enables users to gain hands-on experience, learn correct techniques, and develop critical skills without physical equipment or risking safety hazards. This immersive training approach enhances knowledge retention, improves operational efficiency, and reduces training costs.
- Contextualized Documentation and Maintenance [20]: MR can provide contextualized documentation and maintenance support for engineering products. By overlaying digital information onto physical objects, technicians can access relevant documentation, step-by-step instructions, or annotations directly within their field of view. This capability simplifies complex procedures, reduces errors, and improves maintenance efficiency.

3.7 Benefits of Visualization Technologies in Engineering

Visualizing engineering products through augmented, virtual, and mixed-reality technologies holds immense potential for transforming how complex systems are designed, developed, and interacted with. These technologies offer many benefits, which have been described in previous sections, but to sum up, they are:

- Enhanced Design Iteration: Visualization technologies empower engineers to iterate and refine designs more efficiently. By providing a realistic representation of the product, engineers can identify potential issues, explore alternative design options, and optimize performance before physical prototyping. It reduces costs, accelerates development cycles, and fosters innovation.
- Improved Collaboration: AR, VR, and MR facilitate collaboration among multidisciplinary teams by enabling shared virtual spaces, remote meetings, and real-time annotations. Engineers, designers, and stakeholders can review designs,

provide feedback, and make informed decisions together, irrespective of their physical location. It promotes effective communication, reduces misunderstandings, and streamlines the decision-making process.

- Enhanced Training and Maintenance: Visualization technologies offer immersive training environments for engineers and technicians. Through VR simulations, they can practice assembling, disassembling, and maintaining complex machinery without risking damage to actual equipment. AR overlays can provide real-time instructions, diagnostics, and safety information, aiding technicians in troubleshooting and reducing downtime.
- Customer Engagement and Marketing: Visualizing engineering products using AR and VR opens new customer engagement and marketing avenues. Potential customers can experience products virtually, interact with different configurations, and visualize their integration into real-world settings. It enhances the buying experience, enables personalized customization, and reduces the need for physical prototypes.

3.8 The Future of Visualization Technologies in Engineering

As AR, VR, and MR technologies evolve, their integration into engineering processes is expected to become more seamless and pervasive. Advancements in hardware, such as lightweight and high-resolution displays, will enhance the realism and comfort of these visualization experiences. Additionally, integrating artificial intelligence into these technologies will enable intelligent object recognition, automated design optimizations, and real-time data analysis, further enhancing the visualization capabilities in engineering.

In the future, the following advancements and impacts could be anticipated:

- Real-Time Collaboration: The future of visualization technologies in engineering will involve real-time collaboration on a global scale. Engineers from different disciplines and geographical locations can collaborate seamlessly in shared virtual spaces, enhancing productivity and fostering creativity. It will result in faster decision-making, reduced time to market, and increased innovation.
- Digital Twin Integration [21]: Digital twin technology, which involves creating a virtual replica of a physical product or system, will be seamlessly integrated with visualization technologies. Engineers can visualize real-time data from sensors embedded in physical products, allowing for predictive maintenance, performance optimization, and real-time simulations. This integration will revolutionize how engineering products are monitored, maintained, and improved throughout their lifecycle.
- Enhanced Human–Machine Interaction: With the advancement of visualization technologies, the interaction between humans and machines will become more natural and intuitive. Gesture recognition, voice commands, and haptic feedback

will enable engineers to manipulate and interact with virtual objects more effectively. It will improve the design process and enhance the final products' usability and ergonomics.

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Chapter 4
Software Description of the AR Mobile Application

4.1 A Need for Augmented Reality Mobile Application

Before using Augmented Reality (AR) and its application in engineering graphics, the answer to the primary question should be received: "What is the need for augmented reality in technical drawing?". The following reasons should be considered to answer this question precisely.

AR allows users to overlay digital information in the real world, enhancing the visualization of technical drawings [1]. Using AR-enabled mobile devices, engineers can overlay 3D models, drawings, or specifications directly onto projected geometric objects (parts, assembly units, and so on). Such a visual augmentation helps users understand complex designs, evaluate spatial relationships between elements, and identify main operating characteristics.

AR allows for contextualizing technical drawings in a real environment [2]. It can overlay digital drawings onto real space, providing a better understanding of how a design or structure will fit into the environment. Such contextualization helps make informed decisions and ensure accurate spatial relationships.

AR can facilitate real-time feedback and collaboration between team members [3, 4]. Users of AR devices can view and interact with the same augmented content simultaneously, regardless of location. This capability is helpful for remote groups. It allows involving physically absent experts.

Augmented reality can accelerate design iteration and prototyping [5]. By overlaying virtual design elements onto geometrical objects, engineers can quickly visualize and evaluate different design options without physical prototypes. This capability saves time and resources by enabling rapid experimentation, evaluation, and improvement of new design projects.

AR significantly benefits technical drawing education and training [6], as well as in industrial application, particularly in design [7] and maintenance [8]. Using AR, students and trainees can interact with virtual 3D models, visual guides, and

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V. Ivanov et al., *Augmented Reality for Engineering Graphics*, Springer Tracts in Mechanical Engineering, https://doi.org/10.1007/978-3-031-44641-2_4

step-by-step instructions overlaid on real-world objects. As a result, such an immersive education process improves understanding, retention, and skills development, making learning technical drawing more engaging and highly effective.

Using AR in engineering graphics improves visualization, contextualization, collaboration, design iteration, and learning. It provides valuable tools and opportunities for professional growth within Smart Manufacturing and the Industry 4.0 strategy implementation.

4.2 Actions Before Using the Application

Downloading and Installing. For a clearer understanding of the drawings from the textbook, a mobile application "AR for Engineering Graphics" was developed (Fig. 4.1). It supports smartphones and tablets with an Android-based operating system from Google and an iOS-based operating system from Apple.

The mobile application can be downloaded for OS Android from Google Play via the link https://play.google.com/store/apps/details?id=com.iatdi.textbook_ar and for iOS—from the App Store via the link https://apps.apple.com/gb/app/ar-for-engineering-graphics/id6451407674.

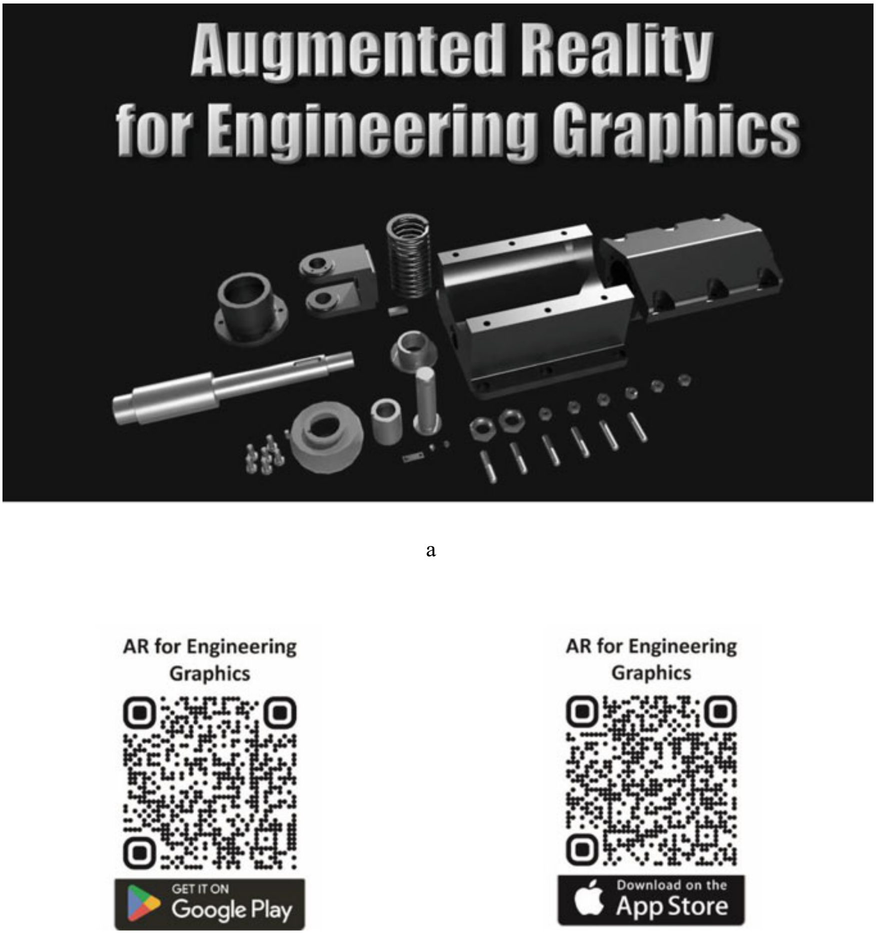
Activation of AR. After installation, the inactivated interface of the mobile application is shown in Fig. 4.2a. To activate the AR, it is necessary to move the screen to one of the 20 markers (e.g., marker 1 is shown in Fig. 4.2b).

All 20 markers are published in Chap. 5 of the present book. Also, you can use separately printed markers (in color or grayscale), as presented in Fig. 4.3a. After the activation, the printed image will be supplemented by AR (Fig. 4.3b). Simultaneously, the interactive Main Menu also appears automatically on the right side of your screen regardless of the vertical or horizontal location of your screen.

The Main Menu contains the following functional elements: "Cross-section", "Start working", "Specification", "Disassembly", and "Exploded view", described in detail in further subsections.

4.3 Functional Capabilities

Functional elements of the Main Menu contain all the necessary elements that simplify the process of reading assembly drawings. In particular, they allow the elements of an assembly unit to be highlighted (simpler assembly units, parts, standard elements, and materials) and visualize assembly and disassembly processes.



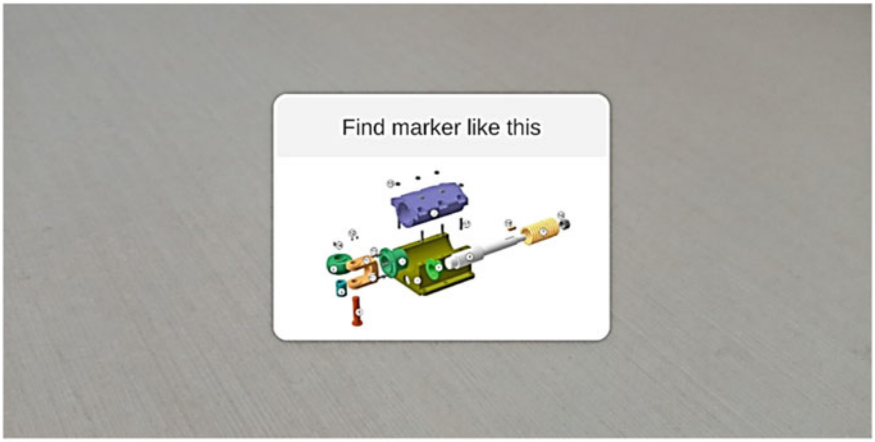
a

b c

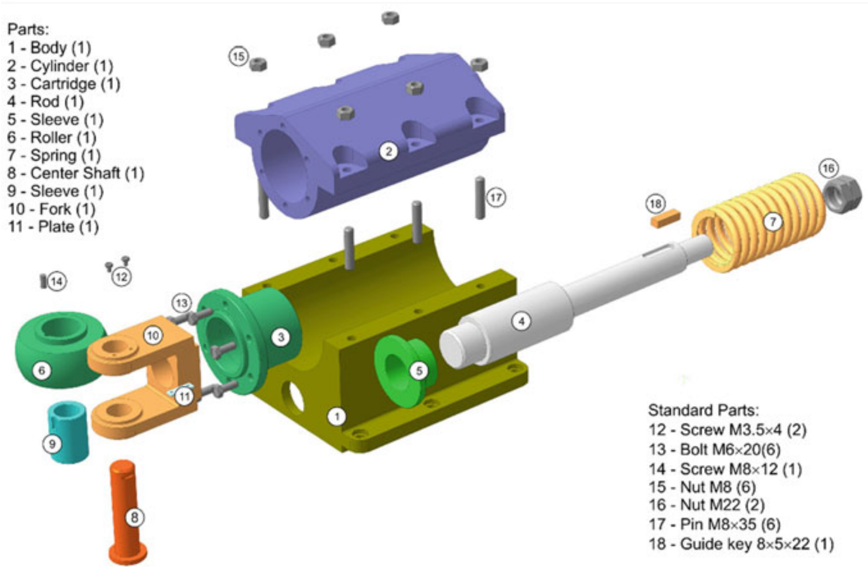
Fig. 4.1 Mobile application "AR for Engineering Graphics" (**a**) on Google Play (**b**) and App Store (**c**)

Cross-Sectional Mode. Since a number of elements of the assembly unit are located inside the body parts, the mobile application provides a sectional view in real-time. Such an opportunity allows for a more in-depth understanding of the primary rules in designing assembly drawings.

To activate the cross-sectional mode (Fig. 4.4), the "Cross Section" button should be pressed. Notably, the cross-section mode is interactive. It allows for changing the depth and the angle of view. The "Cross Section" button should be pressed again to deactivate this mode.

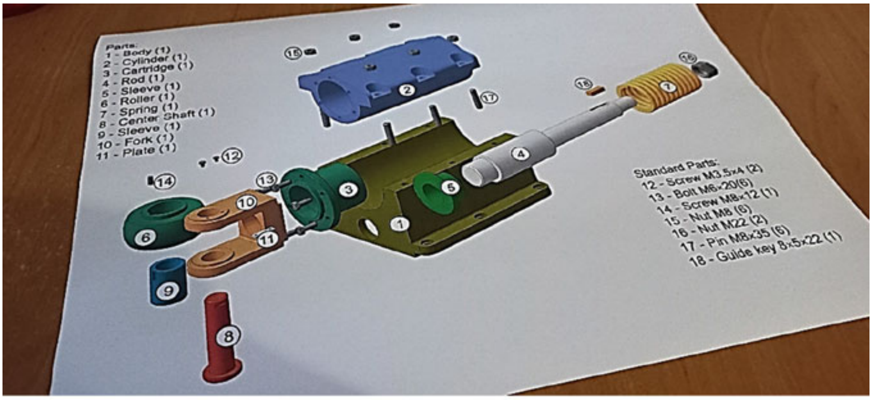


a

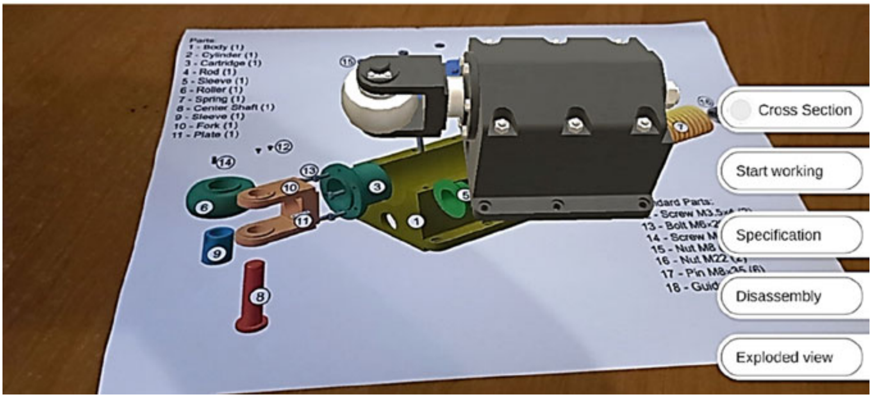


b

Fig. 4.2 Mobile application interface at start (**a**) and marker (**b**)



a



b

Fig. 4.3 Marker (**a**) and activated AR with interacting menu (**b**)

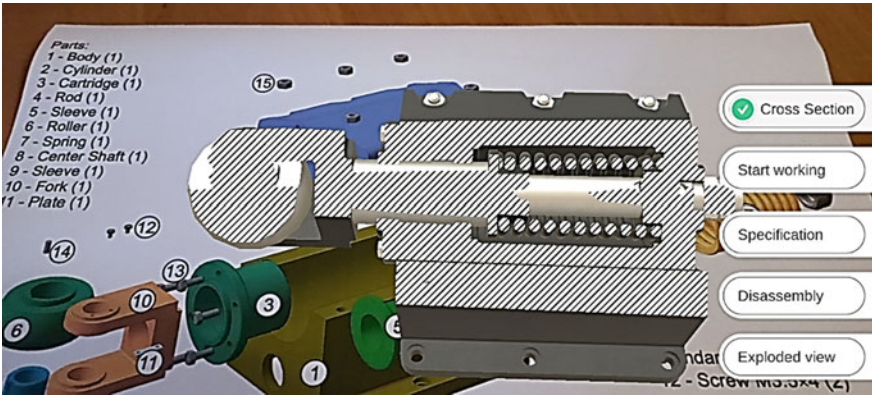


Fig. 4.4 The cross-sectional view

Working Mode. An essential advantage of the mobile application is the ability to visualize the operating processes occurring in the assembly unit (e.g., mechanical movement of working parts, clamping-unclamping of contact pairs, etc.). For better clarity, some elements become transparent to improve the visibility of internal parts and their interactions.

To activate the working mode (Fig. 4.5), the "Start working" button should be pressed. The working mode is also interactive. It allows for changing the angle of view. It can be paused by pressing the button "Pause" and deactivated by the button "Stop" or "Stop working". These options allow for considering the work process in more detail and focusing on functional elements that perform work movements.

Specification. To highlight a particular part of the assembly unit, the "Specification" button should be pressed (Fig. 4.6). In this case, the context menu appears on the left side. This menu contains all the components of the assembly, numbered and titled according to the actual specification. The specification mode can be disabled immediately by pressing the "Go to back" button.

Disassembly Mode. To start the disassembly process (Fig. 4.7), the button "Disassembly" should be pressed. The step-by-step animation will be activated. The "Pause" button (on the left side) can be pressed during the disassembly to more clearly study the step-by-step disassembly process, e.g., enlarge or from different sides. The animation will stop automatically after all components are fully disassembled. The disassembly process can be stopped immediately by pressing the button "Stop". The resulting disassembled view is presented in Fig. 4.7d. Thus, the principle "from the product to individual components" is implemented during disassembly.

Assembly Mode. To start the assembly process (Fig. 4.8), the button "Assembly" should be pressed. This button is enabled after the previously realized disassembly mode.

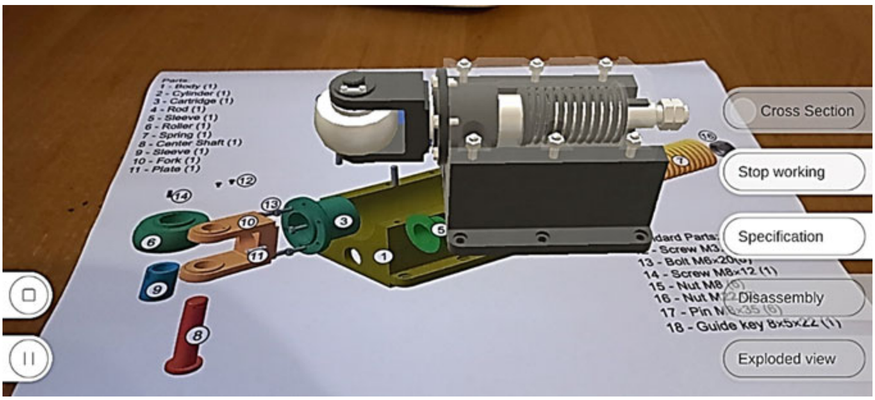
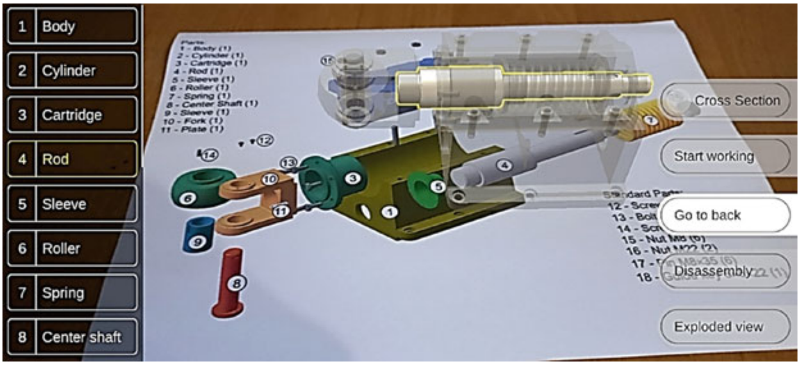
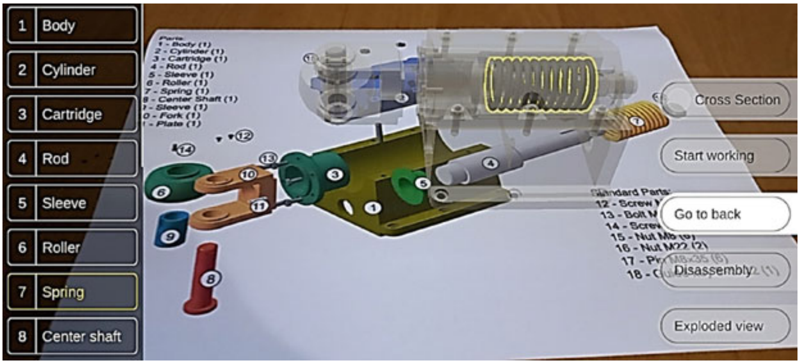


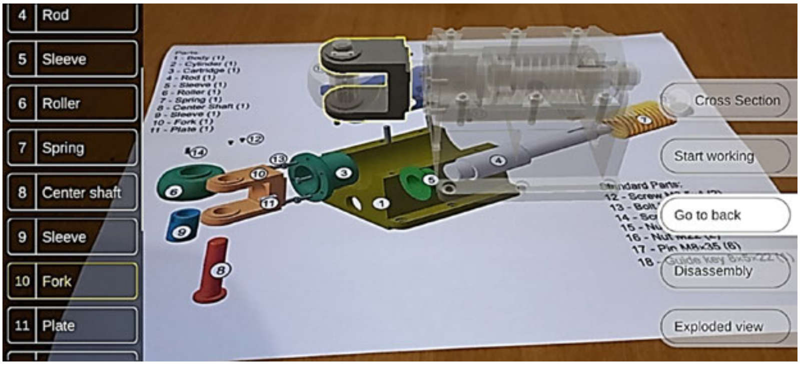
Fig. 4.5 The working mode



a

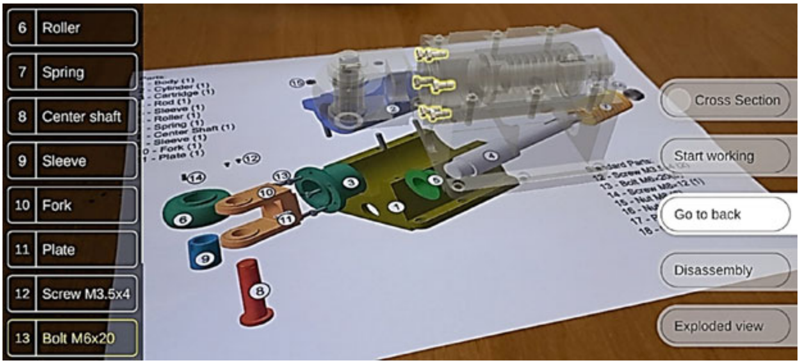


b



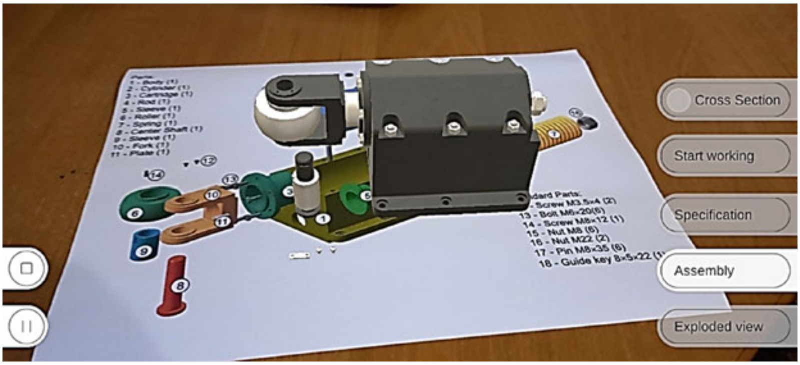
c

Fig. 4.6 Indicating particular assembly elements: **a**—rod; **b**—spring. Indicating particular assembly elements: **c**—fork; **d**—bolt M6x20

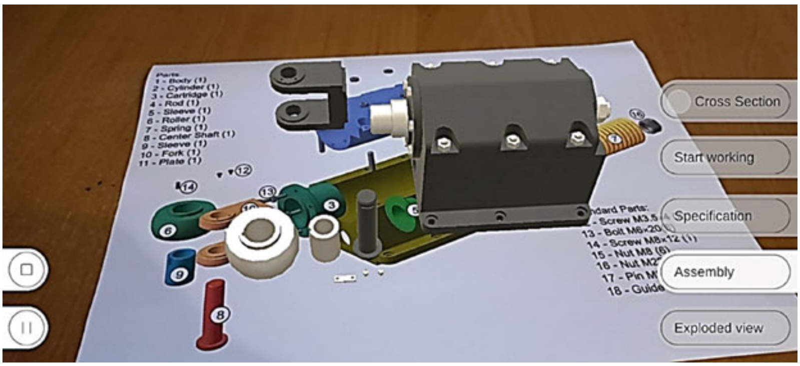


d

Fig. 4.6 (continued)

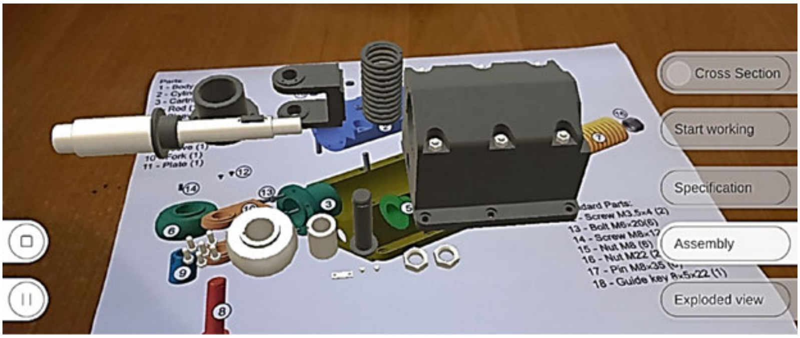


a

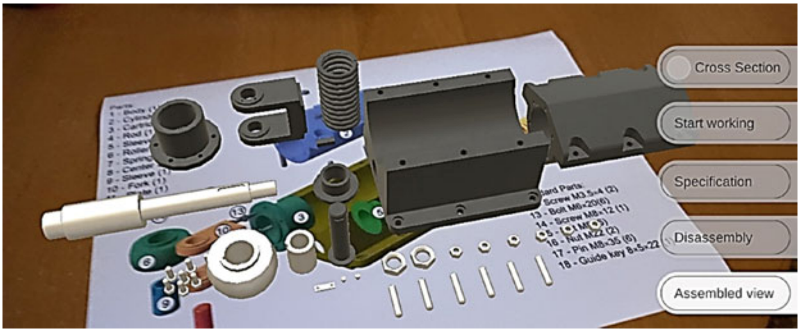


b

Fig. 4.7 The step-by-step (**a**–**c**) disassembly mode and the final disassembled view (**d**)



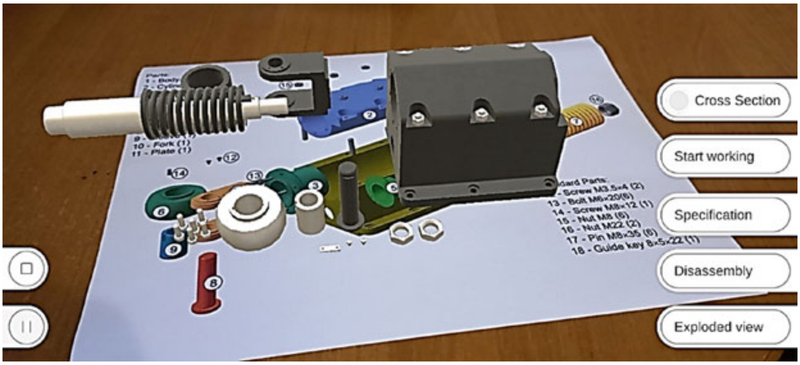
c



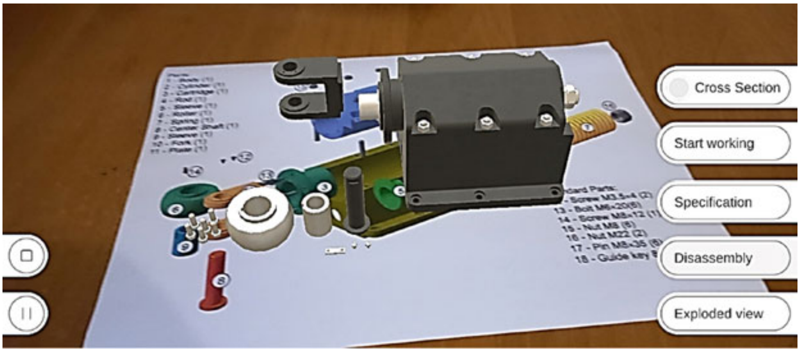
d

Fig. 4.7 (continued)

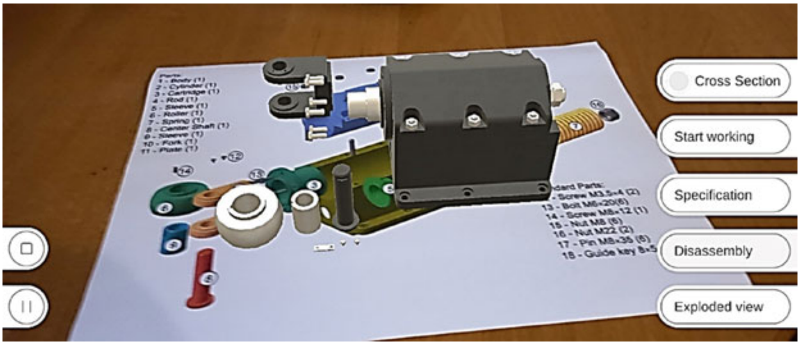
Similar to the previous function, the step-by-step assembly animation starts automatically. The "Pause" button (on the left side) can be pressed during assembly to more clearly study the step-by-step assembly process, such as examining the surfaces of the parts that will mate during assembly. The animation will stop automatically after all components are assembled. Thus, the principle "from individual components to the product" is implemented during the assembly process.



a

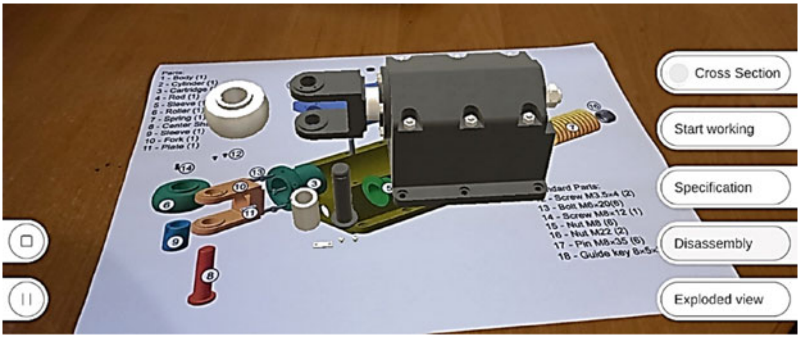


b



c

Fig. 4.8 The step-by-step (**a–d**) assembly mode



d

Fig. 4.8 (continued)

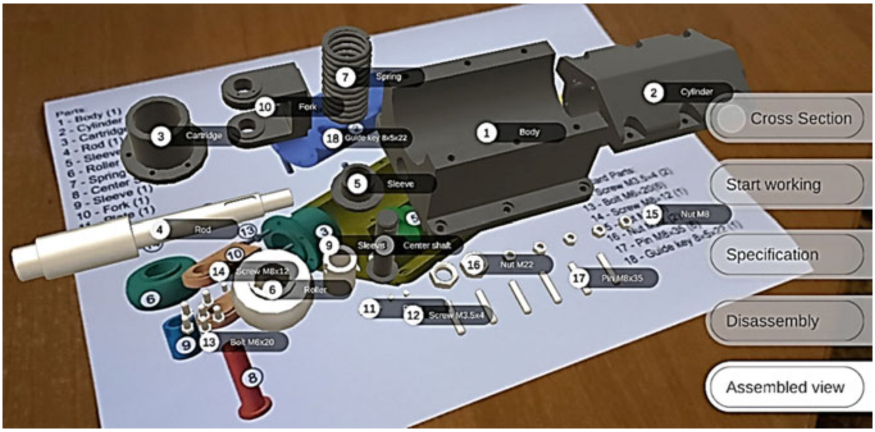


Fig. 4.9 The exploded view

The assembly process can also be stopped immediately by pressing the button "Stop". In this case, the resulting figure completely corresponds to the initial AR model (Fig. 4.3b).

Exploded View. This mode allows for detecting any part of the assembly. For this purpose, the "Exploded view" button should be pressed (Fig. 4.9).

Remarkably, all the elements of the assembly unit are consistent with the specification in terms of position numbers and titles of their elements.

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Chapter 5
Exercises

5.1 General Recommendations

Completion of the above exercises by students of education contributes to the development of the following competencies:

1. Ability to abstract thinking, analysis, and synthesis.
2. Knowledge and understanding of the subject area and understanding of professional activity.
3 Ability to work in a team.

Depending on the number of students in the academic group, the teacher forms teams of 2–4 people each. Each team, in agreement with the teacher, receives a task, the object of which is an assembly product. The general task for each team is:

(a) formulation of the structure and functional purpose (principle of action) of the given assembly product;
(b) designing an assembly 3D model of a given product;
(c) designing of animation of assembly and disassembly of product components;
(d) designing the assembly drawing of the product with the indication of all the necessary information following the current standards:

    (1) image of the assembly unit (views, sections, cross-sections, remote elements), which gives a complete understanding of the design, arrangement, and relationship of the component parts, data for assembly, and control of the functioning of the assembly unit;
    (2) overall dimensions and dimensions for reference;
    (3) dimensions and accuracy of installation and connecting elements;
    (4) dimensions, limit deviations, and surface roughness, which must be performed or controlled according to this assembly drawing;
    (5) other technical requirements;
    (6) technical characteristics (if necessary);

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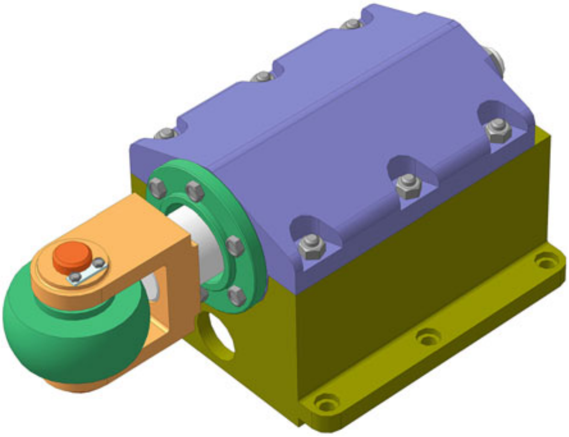


Fig. 5.1 Roller shock absorber (assembly view)

(7) numbering of all component parts of the product following the items specified in the specification.

Each team member, in agreement with the teacher, receives an individual task, the object of which is a separate part of the assembly product (a part or a series of parts). The task for each team member is:

(e) formulation of the functional purpose of the specified part (parts);
(f) designing a 3D model of a given part (parts);
(g) designing the working drawing of the specified part (parts) with the indication of all the necessary information following the current standards:

(1) image of the part (views, sections, cross-sections, remote elements), which gives a complete understanding of the design, placement, and interconnection of surfaces, data for manufacturing, and quality control;
(2) dimensions: overall, connecting, dimensions of individual elements of the part, dimensions for reference;
(3) size tolerances;
(4) roughness of the part surfaces;
(5) tolerances on the shape and geometric relationship of surfaces;
(6) technical requirements that should be ensured during the manufacturing of the part (heat treatment, coating, etc.);
(7) additional data necessary for the manufacturing and control of the part;
(8) special requirements for jointly processed parts;
(9) the part material.

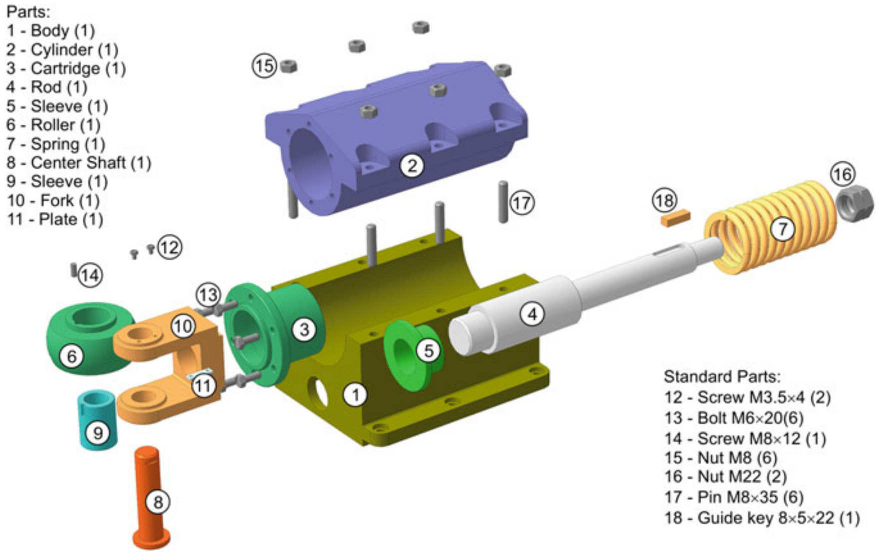


Fig. 5.2 Roller shock absorber (exploded view)

5.2 Exercise 1—Roller Shock Absorber

Brief Description of the Product. The roller shock absorber is used to guide the workpieces moved during rolling and absorb shock loads (Fig. 5.1).

The beat when feeding the workpiece is transmitted from roller 6 (Fig. 5.2) on the spring 7 shock absorber through rod 4. Fork 10 is installed at the end of the rod, which can only move in the axial direction, for which there is a guide key 18. The initial force of pressing the spring on the roller is adjusted using the screw nut 16. To the rubbing surfaces of the roller parts through the channels of the center shaft 8 is lubricated.

Cylinder 2 is attached to body 1 with six pins 17 and nuts 15. The six bottom holes in the body are for attaching the roller shock absorber to the frame or bed of the unit.

The list of components of the roller shock absorber (Fig. 5.3) is specified in Table 5.1.

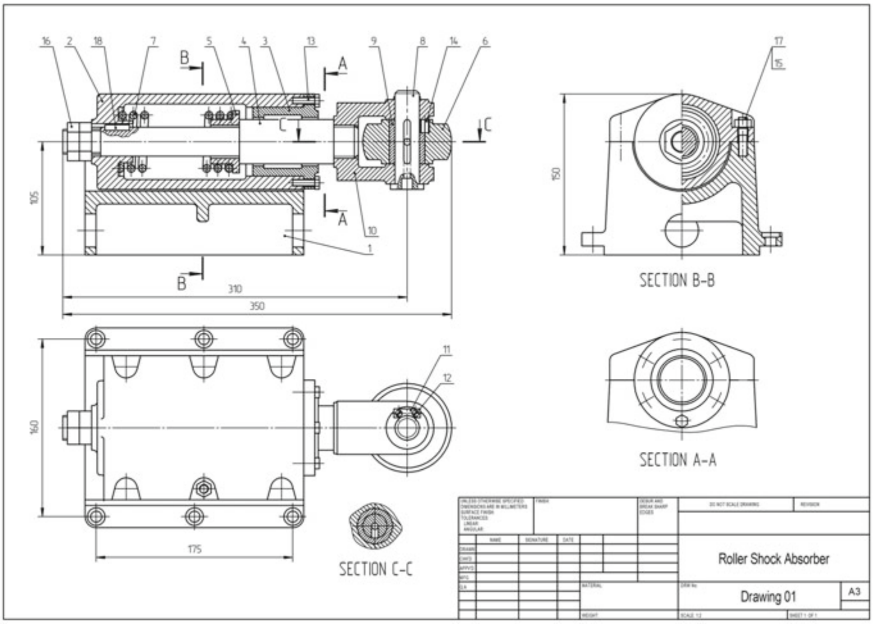


Fig. 5.3 Roller shock absorber (drawing)

5.3 Exercise 2—Hydraulic Crane

Brief Description of the Product. The plug-type hydraulic crane (Fig. 5.4) is intended for switching the fuel supplied from the main and additional tanks to the fuel pump.

The crane consists of a cast iron body 1 (Fig. 5.5), on which there are two mounts for fixturing; plug 2 for overlapping holes; packing nut 3 and handle 4, with the help of which the plug is turned.

The list of components of the hydraulic crane (Fig. 5.6) is specified in Table 5.2.

Table 5.1 Parts list

Item	Part name	Quantity
Parts		
1	Body	1
2	Cylinder	1
3	Cartridge	1
4	Rod	1
5	Sleeve	1
6	Roller	1
7	Spring	1
8	Center shaft	1
9	Sleeve	1
10	Fork	1
11	Plate	1
Standard parts		
12	Screw M3.5 × 4	2
13	Bolt M6 × 20	6
14	Screw M8 × 12	1
15	Nut M8	6
16	Nut M22	2
17	Pin M8 × 35	6
18	Guide key 8 × 5 × 22	1

5.4 Exercise 3—Puller

Brief Description of the Product. The puller (Fig. 5.7) is used when dismantling the hub of the car. The bolts 2 (Fig. 5.8) are screwed into the corresponding sockets of the hub, and the heel moves by rotating the lead screw 3. At the same time, it rests against the axle shaft and squeezes the last one out of the hub.

The list of components of the puller (Fig. 5.9) is specified in Table 5.3.

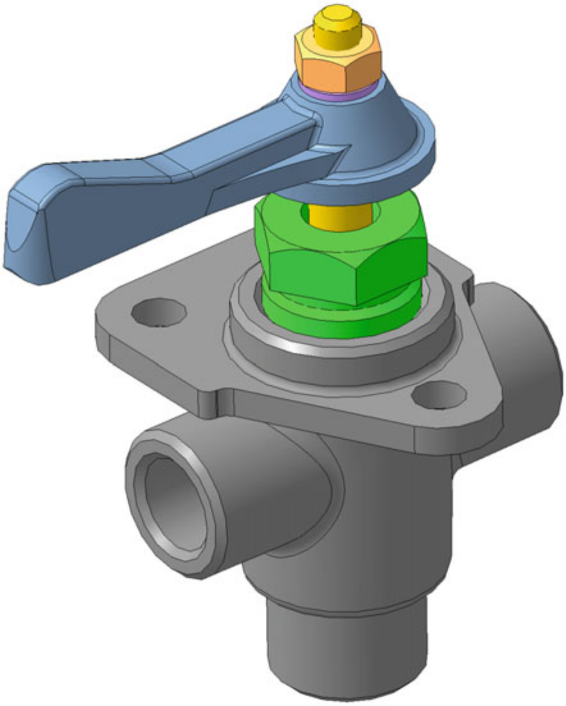


Fig. 5.4 Hydraulic crane (assembly view)

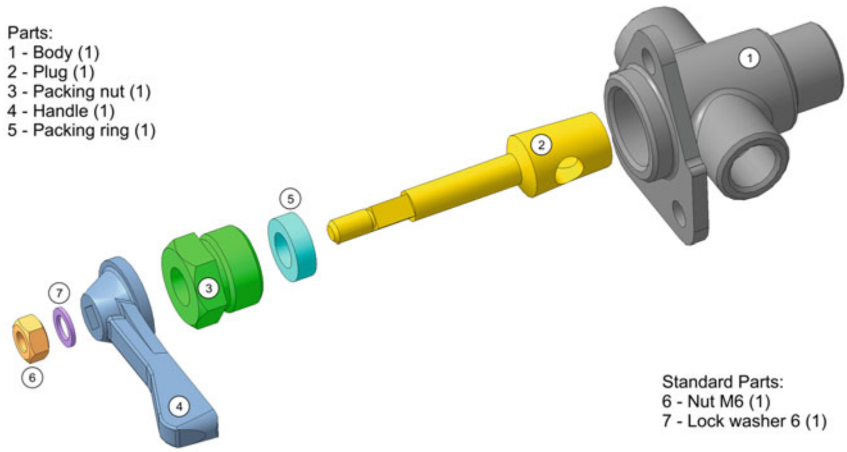


Fig. 5.5 Hydraulic crane (exploded view)

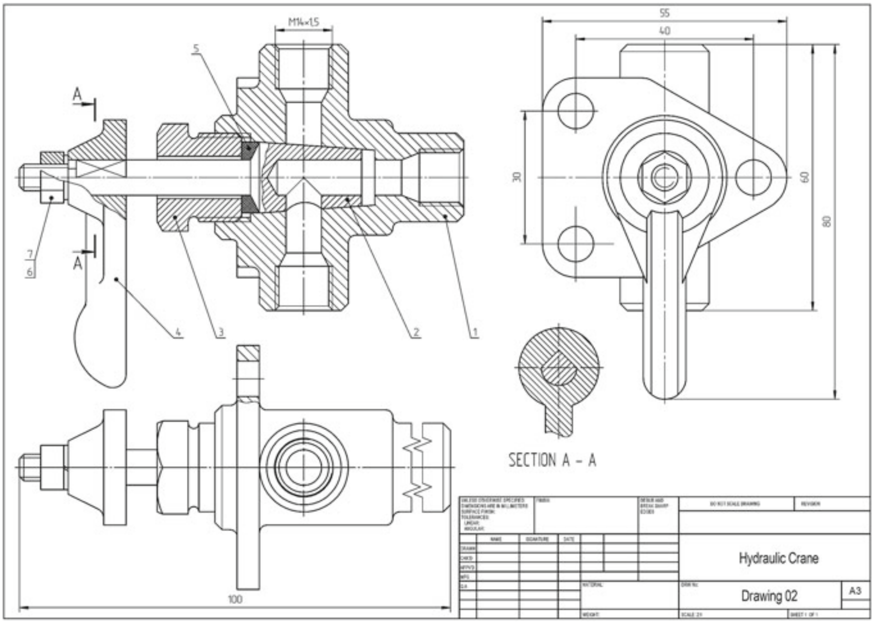


Fig. 5.6 Hydraulic crane (drawing)

Table 5.2 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			Standard parts		
1	Body	1	6	Nut M6	1
2	Plug	1	7	Lock washer 6	1
3	Packing nut	1			
4	Handle	1			
5	Packing ring	1			

5.5 Exercise 4—Carriage

Brief Description of the Product. The carriage of the overhead conveyor (Fig. 5.10) is used to move goods along a monorail (or I-beam) and is used in warehouses, farms, and workshops. It is also an integral part of the undercarriage (electric hoist), which is supplied with a manual or machine drive.

The carriage consists of a suspension bar and two symmetrical roller parts (Fig. 5.11). Roller 2 (carriage wheel) is mounted on center pin 5 on ball bearings. The center pin is fixed in bracket 1. The suspension is rigidly fixed between the planes of the brackets.

The list of components of the carriage (Fig. 5.12) is specified in Table 5.4.

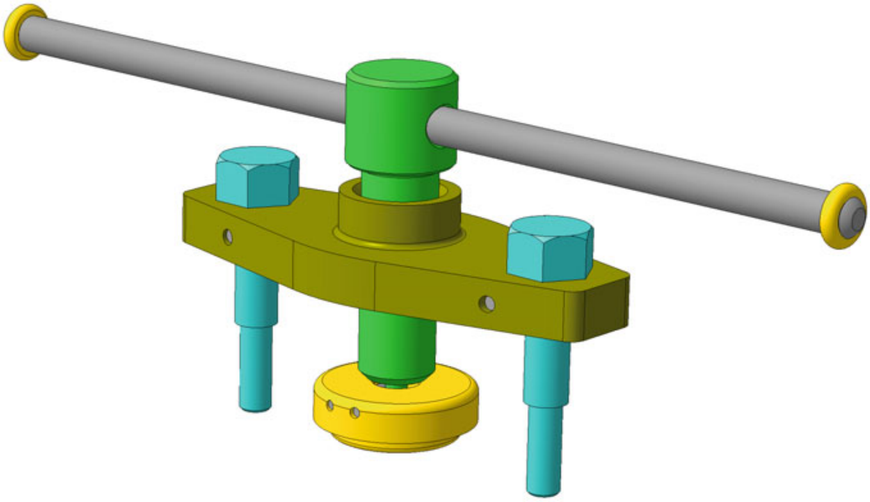


Fig. 5.7 Puller (assembly view)

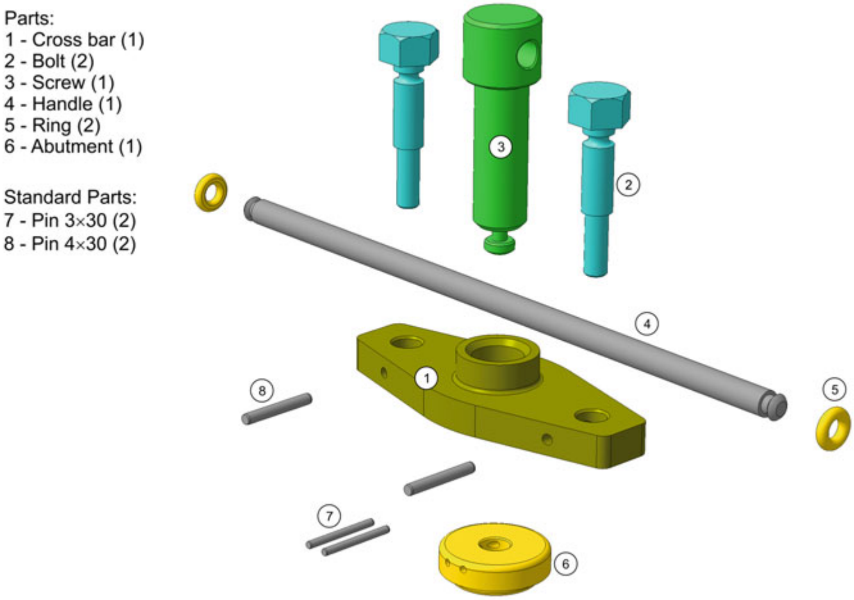


Fig. 5.8 Puller (exploded view)

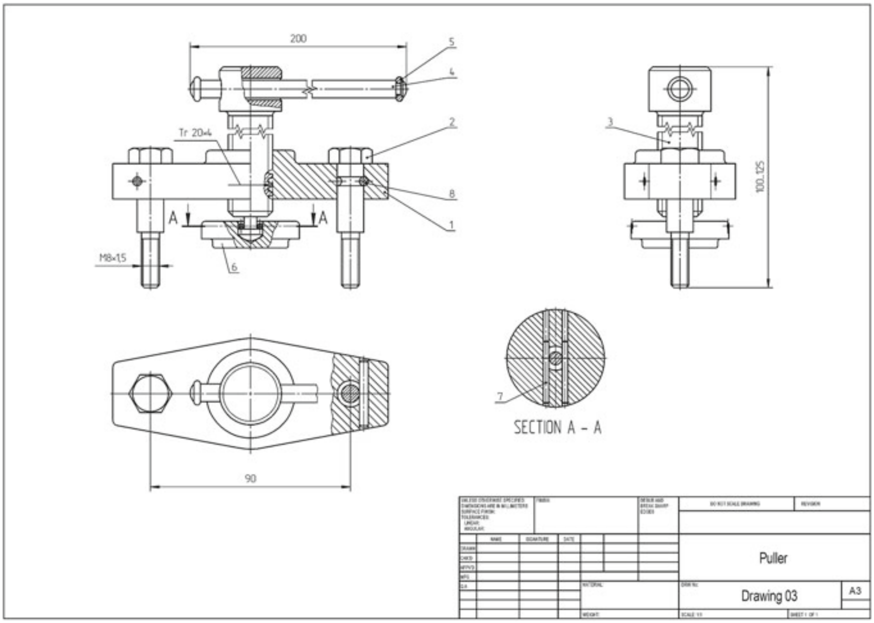


Fig. 5.9 Puller (drawing)

Table 5.3 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			Standard parts		
1	Cross bar	1	7	Pin 3 × 30	2
2	Bolt	2	8	Pin 4 × 30	2
3	Screw	1			
4	Handle	1			
5	Ring	2			
6	Abutment	1			

5.6 Exercise 5—Wheel

Brief Description of the Product. The wheel (Fig. 5.13) is used in a trolley designed for transporting workpieces and finished products in a machine workshop.

In two holes of bracket 1, fixed center pin 3 (Fig. 5.14). In body 2, two ball bearings 14 are pressed, which are clamped by cover 4 and spacer bush 6. In covers 4 and 5, there are grooves for sealing rings 12 and 13, which prevent dust from entering the bearings. On the cylindrical surface of the body, bandage 7 is tensioned, which is pressed by cover 4. The wheel is attached to the base of the cart with four bolts.

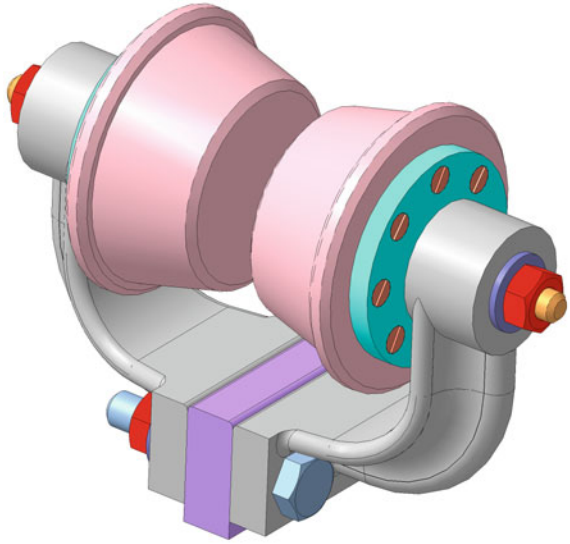


Fig. 5.10 Carriage (assembly view)

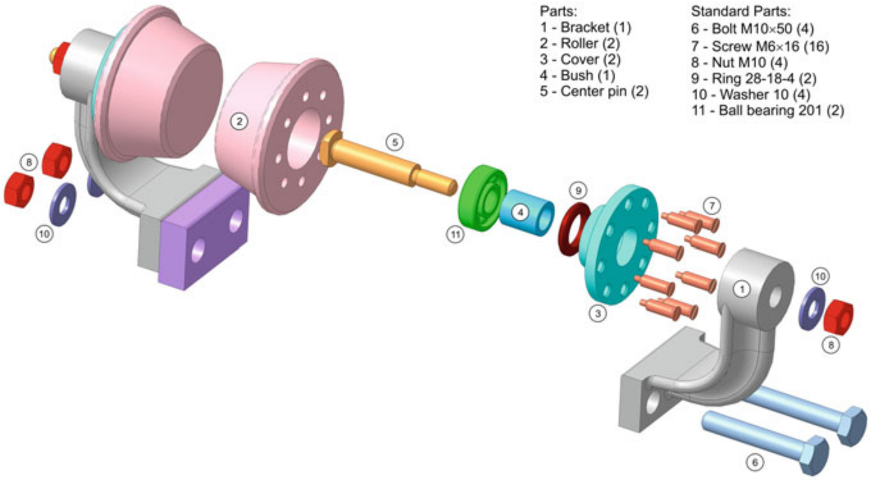


Fig. 5.11 Carriage (exploded view)

The list of components of the wheel (5.15) is specified in Table 5.5.

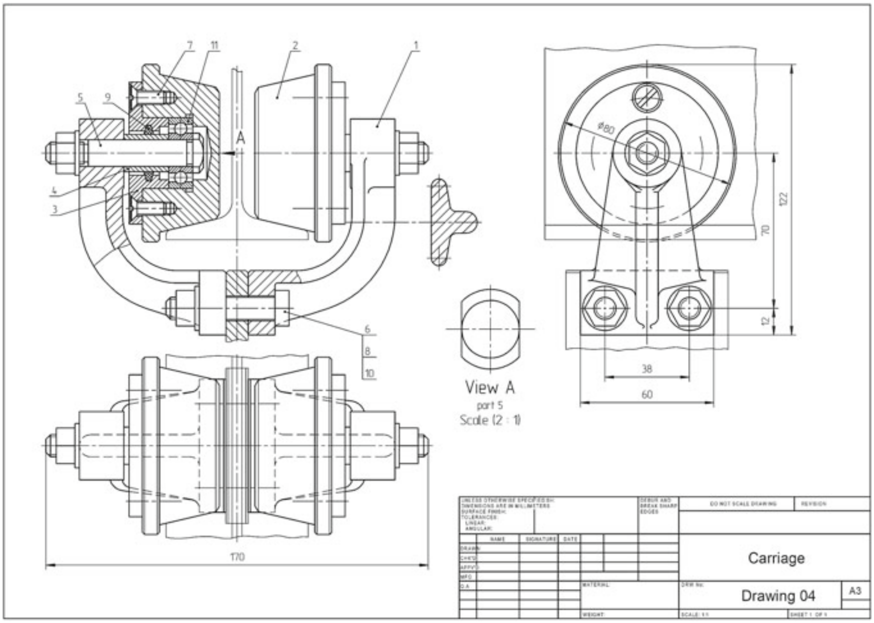


Fig. 5.12 Carriage (drawing)

Table 5.4 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			Standard parts		
1	Bracket	2	6	Bolt M10 × 50	4
2	Roller	2	7	Screw M6 × 16	16
3	Cover	2	8	Nut M10	4
4	Bush	2	9	Ring 28-18-4	2
5	Center pin	2	10	Washer 10	4
			11	Ball bearing 201	2

5.7 Exercise 6—Traveling Wheel

Brief Description of the Product. The traveling wheel (Fig. 5.16) of the under-crane trolley serves as a support for it and guides the trolley along the rail.

The wheel is mounted on two roller bearings 12 (Fig. 5.17) on the center pin 5, fixed by the center pin holder 4 in the carriage frame.

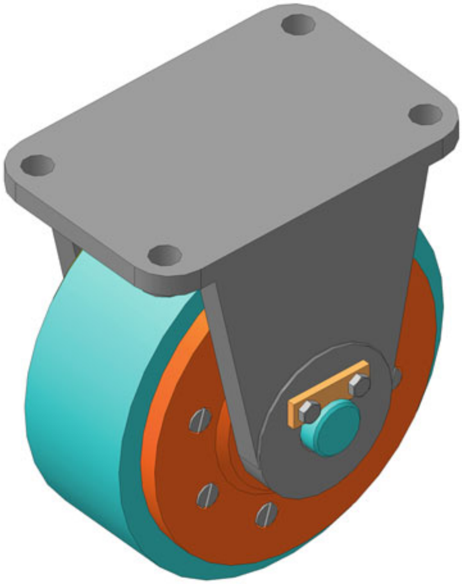


Fig. 5.13 Wheel (assembly view)

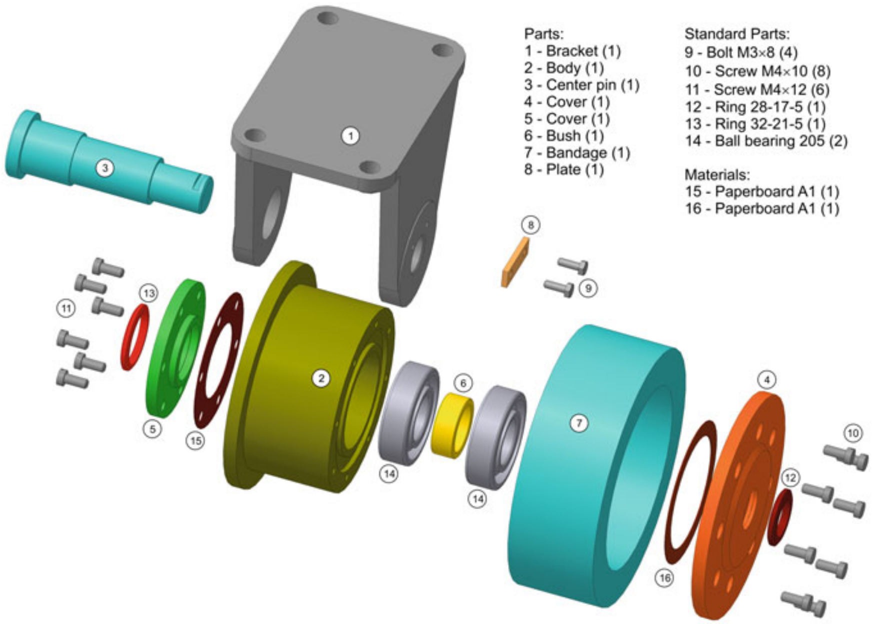


Fig. 5.14 Wheel (exploded view)

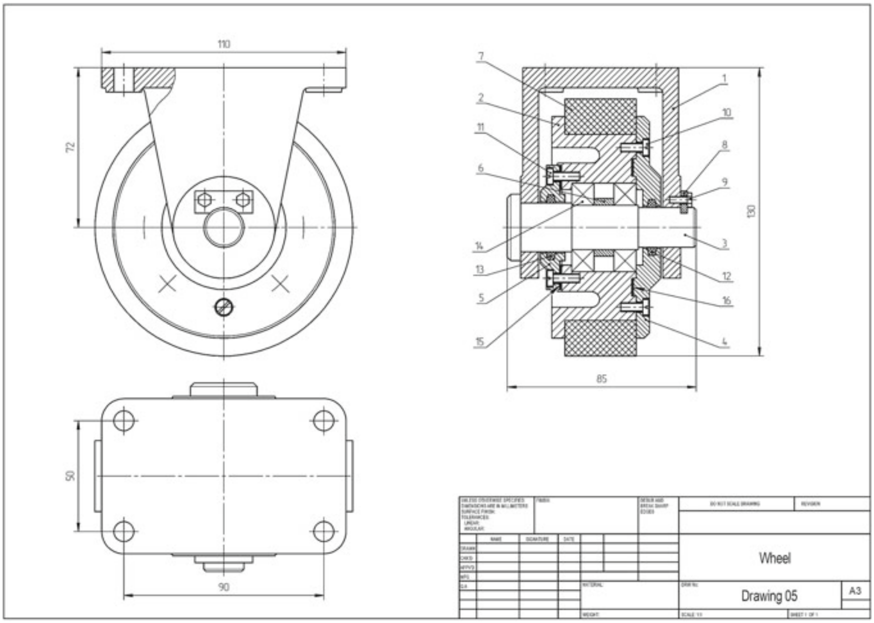


Fig. 5.15 Wheel (drawing)

Table 5.5 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			Standard parts		
1	Bracket	1	9	Bolt M3 × 8	2
2	Body	1	10	Screw M4 × 10	8
3	Center pin	1	11	Screw M4 × 12	6
4	Cover	1	12	Ring 28-17-5	1
5	Cover	1	13	Ring 32-21-5	1
6	Bush	1	14	Ball bearing 205	2
7	Bandage	1	Materials		
8	Plate	1	15	Paperboard A1	1
			16	Paperboard A1	1

In the wheel hub, the bearings are fixed with two covers 3 and a spacer sleeve 2. The covers have a stuffing box that protects the bearing from contamination. Bearings are periodically lubricated with a lubricator 11.

The list of components of the traveling wheel (Fig. 5.18) is specified in Table 5.6.

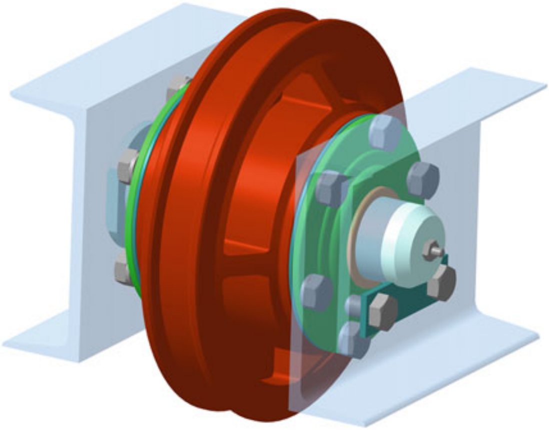


Fig. 5.16 Traveling wheel (assembly view)

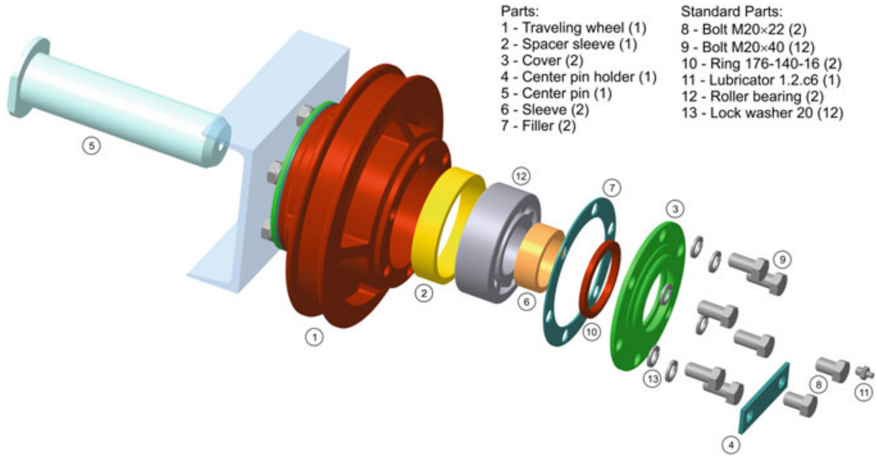


Fig. 5.17 Traveling wheel (exploded view)

5.8 Exercise 7—Gear Pump

Brief Description of the Product. Gear pumps (Fig. 5.19) are used to supply fluid under pressure up to 0.03 Pa. They are used to supply liquid, lubricants, and fuel. High-pressure gear pumps (0.06–0.07 Pa) are used to a limited extent and are manufactured with great care. Gear pumps are simple in design and have a small number of parts but are sensitive to fluid contamination, so an inlet filter should be used.

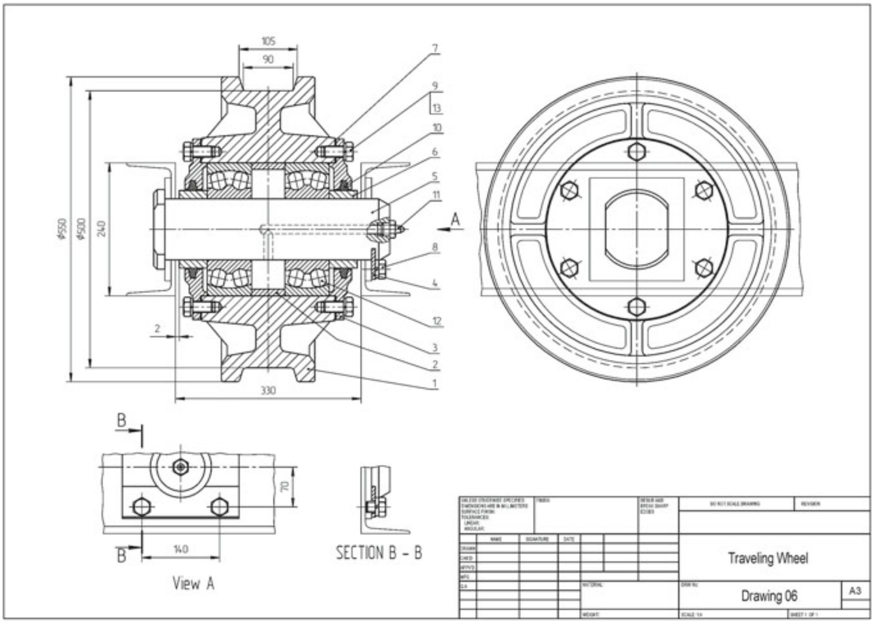


Fig. 5.18 Traveling wheel (drawing)

Table 5.6 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			Standard parts		
1	Traveling wheel	1	8	Bolt M20 × 22	2
2	Spacer sleeve	1	9	Bolt M20 × 40	12
3	Cover	2	10	Ring 176-140-16	2
4	Center pin holder	1	11	Lubricator 1.2.c6	1
5	Center pin	1	12	Roller bearing 3615	2
6	Sleeve	2	13	Lock washer 20	12
7	Filler	2			

The pump work gears 4 (Fig. 5.20) rotate in opposite directions. The gear teeth, disengaging, create a reduced pressure, as a result of which the lubricant enters the suction zone and, in the cavities between the gear teeth, is transferred (along the periphery) to the discharge zone, where it is displaced by the teeth, which enter into an engagement. An increased pressure is created in the discharge zone, under the influence of which the lubricant enters the pipeline. The pump is made on plain bearings with a cast-iron body 1 and cover 5; it has a check valve 10 at pressure.

The list of components of the gear pump (Fig. 5.21) is specified in Table 5.7.

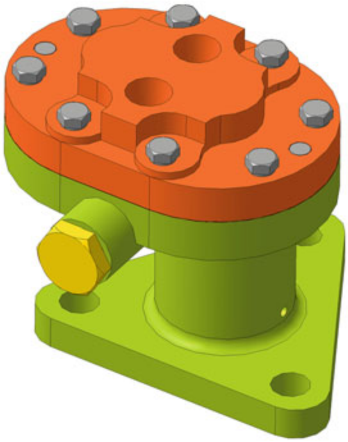


Fig. 5.19 Gear pump (assembly view)

5.9 Exercise 8—Gear Pump

Brief Description of the Product. The car's gear pump (Fig. 5.22) is used to supply lubricant to the rubbing parts of the engine. The pump is installed in the engine body and mounted on the fourth main bearing cap using a bracket integral to the pump body.

The pump is driven by the engine camshaft gear through an intermediate shaft. When the leading shaft 2 (Fig. 5.23) rotates, the lubricant from the oil pan (through the oil receiver) enters the suction zone and, in the gashes between the teeth of the gear wheels 6, rotating in opposite directions, is transferred (distilled) to the discharge zone. Lubricant is forced out of the gashes by the meshing teeth and accumulates in the discharge zone. As a result, the pressure increases, and the lubricant is sent to the coarse filter. From the filter, it enters the lubrication line.

The list of components of the gear pump (Fig. 5.24) is specified in Table 5.8.

5.10 Exercise 9—Clip

Brief Description of the Product. The clip (Fig. 5.25) is used in load-lifting mechanisms. The hoisting mechanism cable (not shown in the figure) envelops block 3 (Fig. 5.26), where a replaceable sleeve 8 is pressed. Block 3 rotates on pin 6. Inside the center pin, some channels are filled with grease through a hole closed by screw 11. Pin 6 is supported by fork 1, connected by pin 7 to suspension 2, and rotating around this pin. A lifting hook is screwed into the threaded hole of suspension 2 (not shown in the figure).

The list of components of the clip (Fig. 5.27) is specified in Table 5.9.

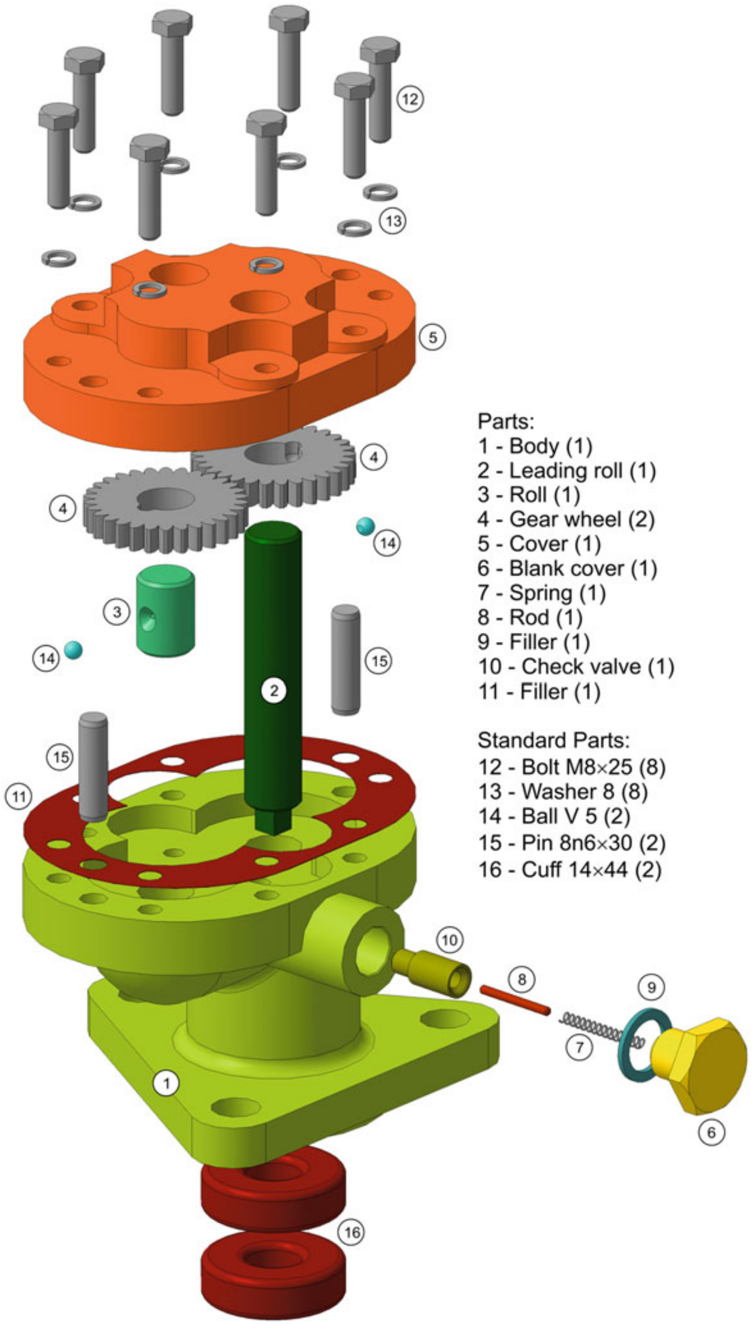


Fig. 5.20 Gear pump (exploded view)

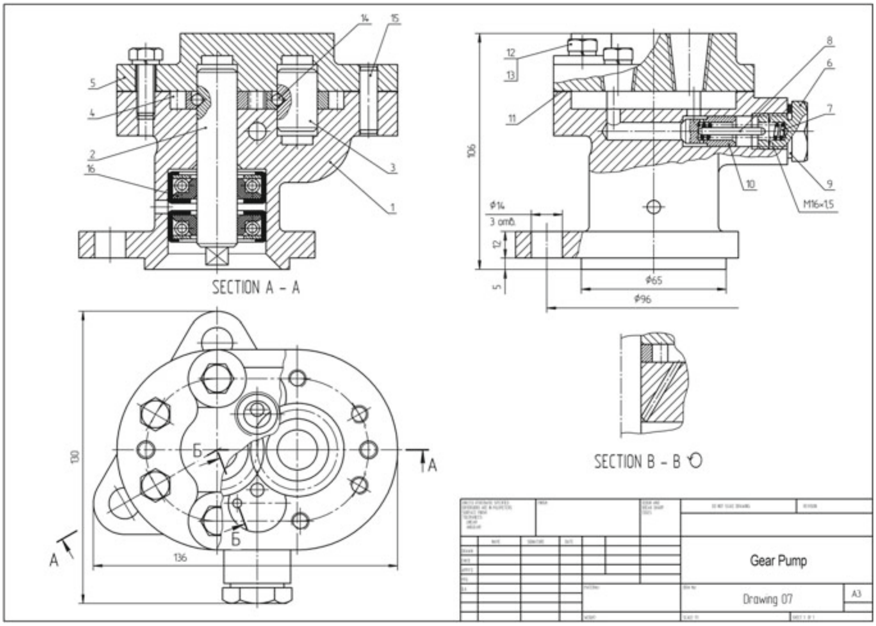


Fig. 5.21 Gear pump (drawing)

Table 5.7 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			9	Filler	1
1	Body	1	10	Check valve	1
2	Leading roll	1	11	Filler	1
3	Roll	1	Standard parts		
4	Gear wheel	2	12	Bolt M8 × 25	8
5	Cover	1	13	Washer 8	8
6	Blank cover	1	14	Ball V 5	2
7	Spring	1	15	Pin 8n6 × 30	2
8	Rod	1	16	Cuff 14 × 44	2

5.11 Exercise 10—Spool Pneumatic Apparatus

Brief Description of the Product. The spool pneumatic apparatus (Fig. 5.28) is designed to disconnect the working chamber from the supply line and communicate this chamber with the atmosphere when the input lever is deflected at a given angle.

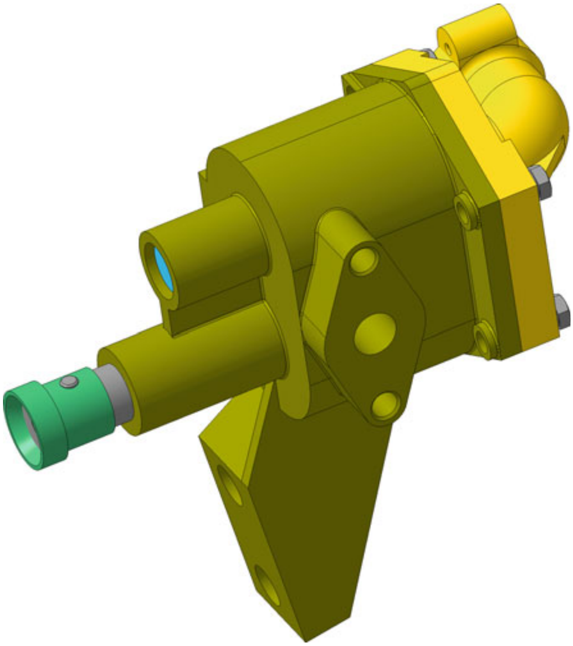


Fig. 5.22 Gear pump (assembly view)

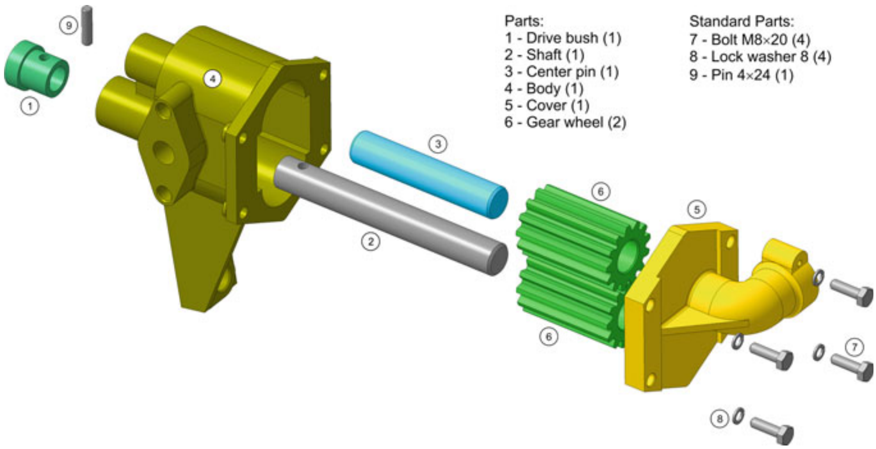


Fig. 5.23 Gear pump (exploded view)

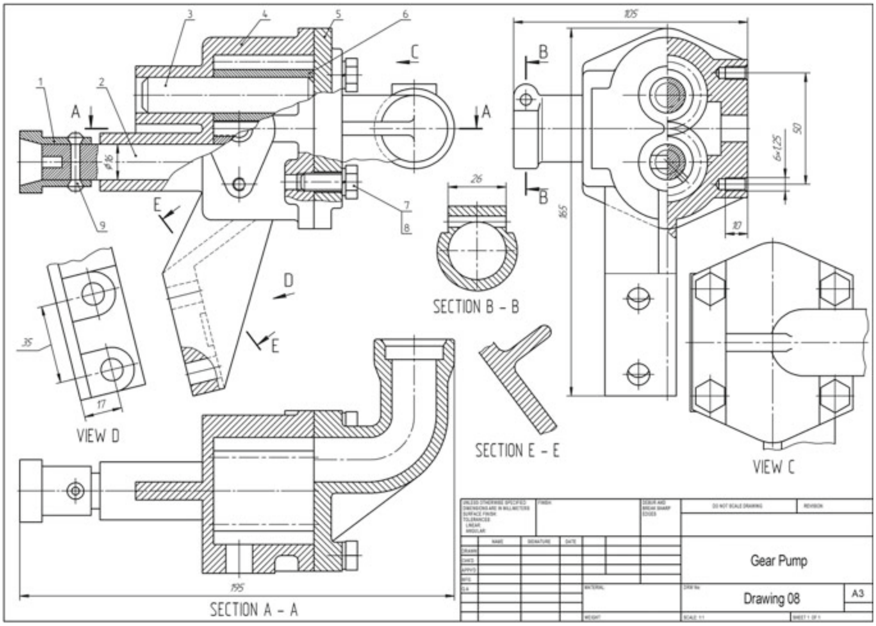


Fig. 5.24 Gear pump (drawing)

Table 5.8 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			Standard parts		
1	Drive bush	1	7	Bolt M8 × 20	4
2	Shaft	1	8	Lock washer 8	4
3	Center pin	1	9	Pin 4 × 24	1
4	Body	1			
5	Cover	1			
6	Gear wheel	2			

When the lever is returned to its original position, the spool separates the chamber from the atmosphere and connects it to the line. Lubricant is supplied to the rubbing surfaces of the spool valve using piston 8 (Fig. 5.29).

The list of components of the spool pneumatic apparatus (Fig. 5.30) is specified in Table 5.10.

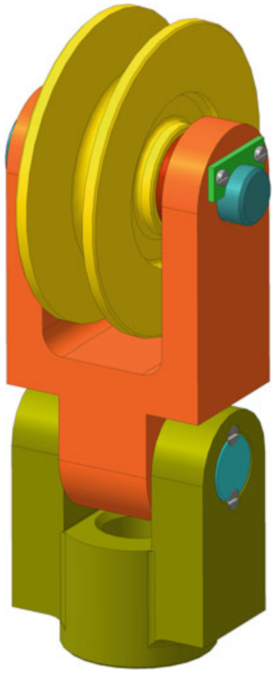


Fig. 5.25 Clip (assembly view)

5.12 Exercise 11—Valve Pneumatic Apparatus

Brief Description of the Product. The air valve (Fig. 5.31) of the brake cock is used to supply compressed air from the air cylinder to the brake chambers. It consists of body 6, valve 1, valve seat 2, push-rod 4, and spring 5 (Fig. 5.32).

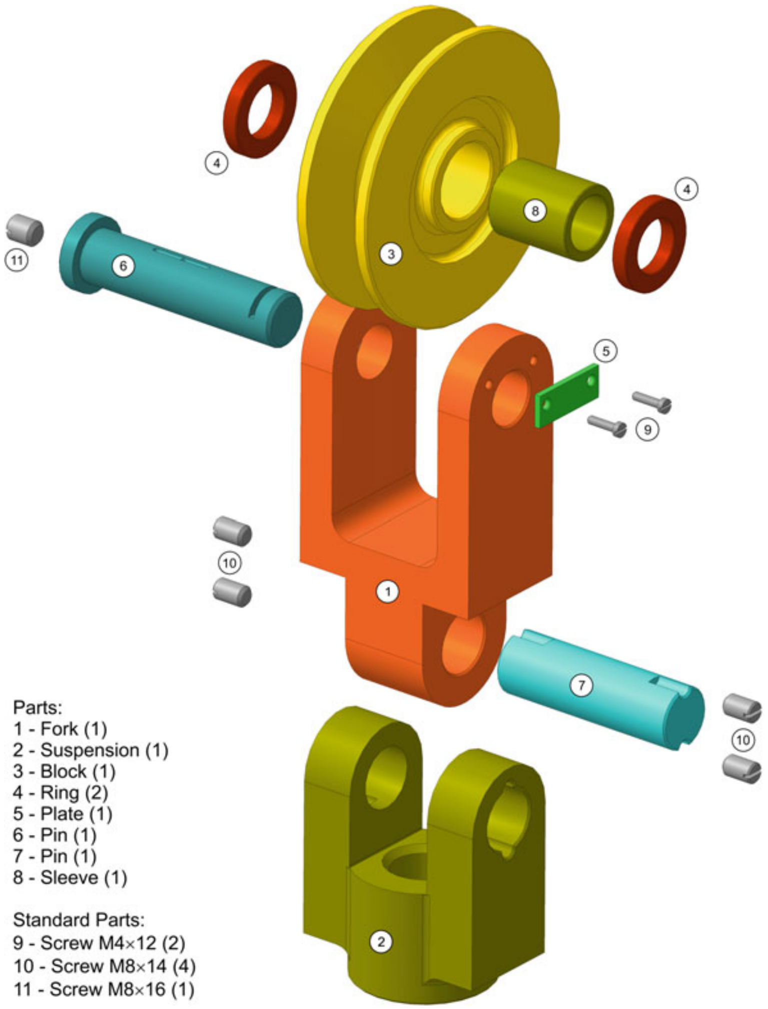


Fig. 5.26 Clip (exploded view)

The air valve opens when the brake pedal is pressed. Compressed air from the cylinder enters the brake chambers. When the brake pedal is released, the spring lifts the push-rod and closes the valve. It cuts off the compressed air supply to the brake chambers.

The list of components of the valve pneumatic apparatus (Fig. 5.33) is specified in Table 5.11.

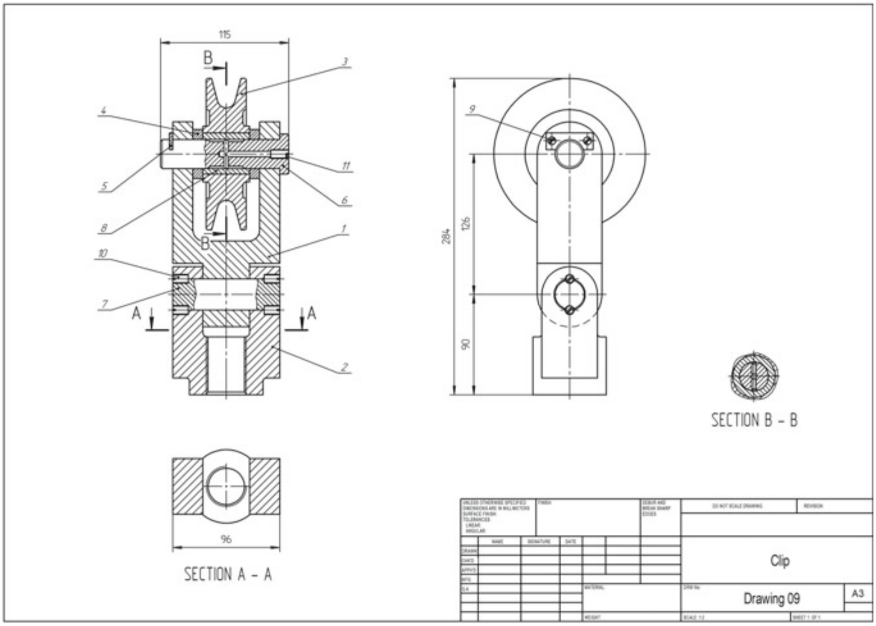


Fig. 5.27 Clip (drawing)

Table 5.9 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			Standard parts		
1	Fork	1	9	Screw M4 × 12	2
2	Suspension	1	10	Screw M8 × 14	4
3	Block	1	11	Screw M8 × 16	1
4	Ring	2			
5	Plate	1			
6	Pin	1			
7	Pin	1			
8	Sleeve	1			

5.13 Exercise 12—Pneumatic Reducing Valve

Brief Description of the Product. The pneumatic reducing valve (Fig. 5.34) is designed to regulate—limit and maintain a constant pressure of the working medium in the pipeline.

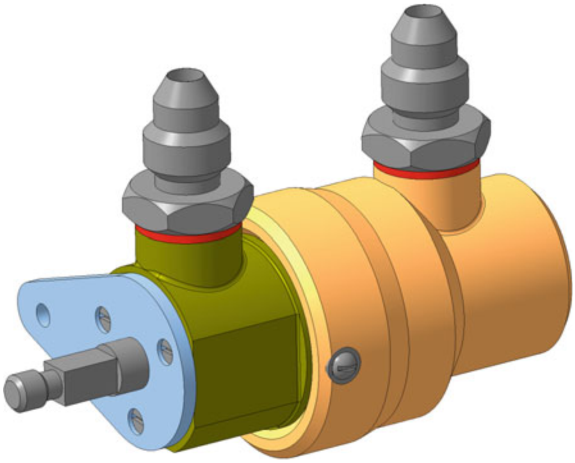


Fig. 5.28 Spool pneumatic apparatus (assembly view)

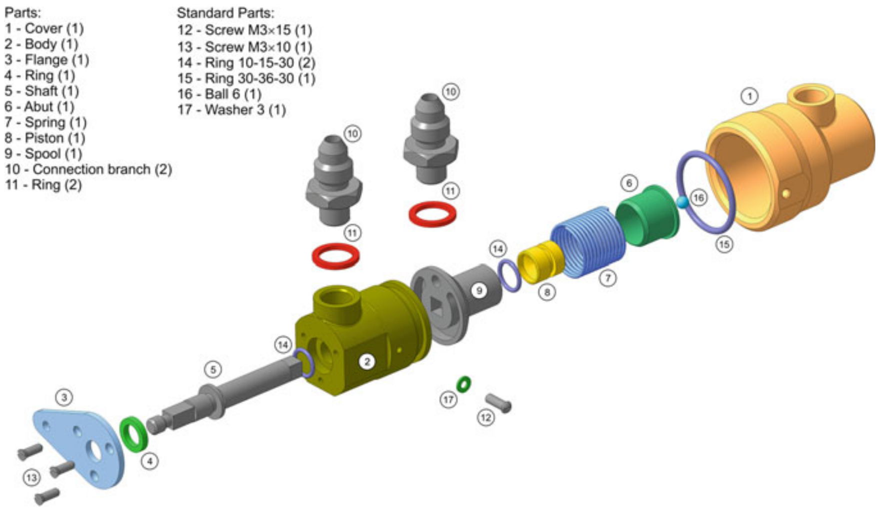


Fig. 5.29 Spool pneumatic apparatus (exploded view)

The allowable pressure in the outlet branch is limited by plunger 3 (Fig. 5.35), which closes the pipeline when the pressure rises above the prescribed one and is regulated by pressing cover 2 on spring 4.

The list of components of the pneumatic reducing valve (Fig. 5.36) is specified in Table 5.12.

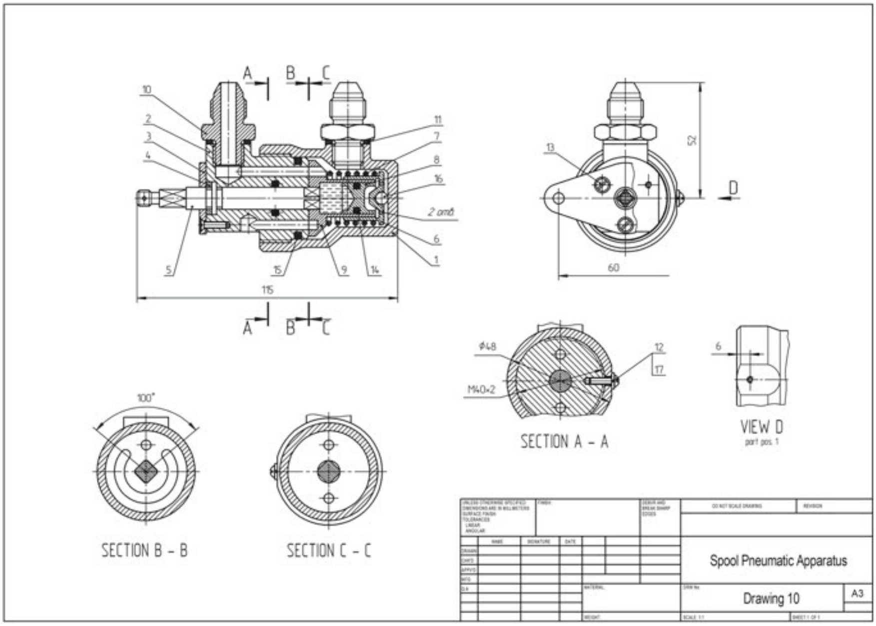


Fig. 5.30 Spool pneumatic apparatus (drawing)

Table 5.10 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			Standard parts		
1	Cover	1	12	Screw M3 × 15	1
2	Body	1	13	Screw M3 × 10	1
3	Flange	1	14	Ring 010-015-30	2
4	Ring	1	15	Ring 030-036-30	1
5	Shaft	1	16	Ball 10–10	1
6	Abut	1	17	Washer 3	1
7	Spring	1			
8	Piston	1			
9	Spool	1			
10	Connecting branch	2			
11	Ring	2			

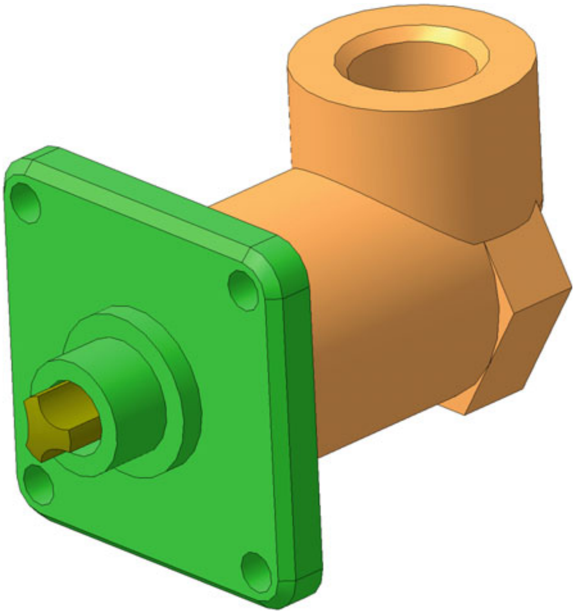


Fig. 5.31 Valve pneumatic apparatus (assembly view)

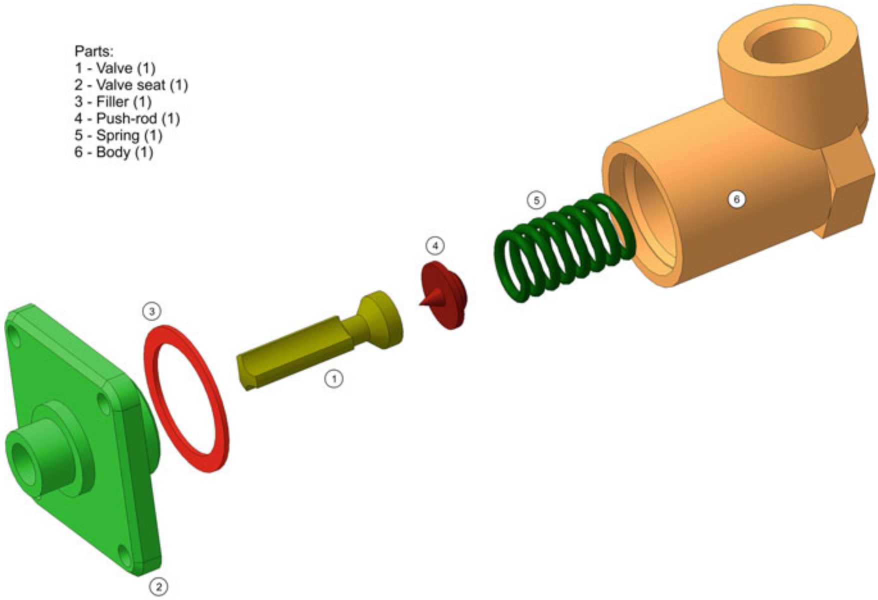


Fig. 5.32 Valve pneumatic apparatus (exploded view)

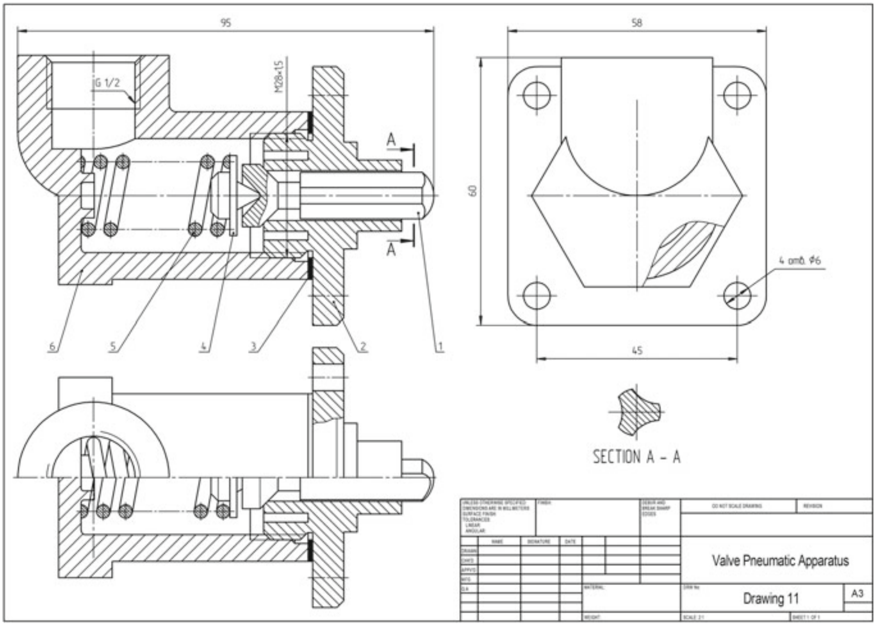


Fig. 5.33 Valve pneumatic apparatus (drawing)

Table 5.11 Parts list

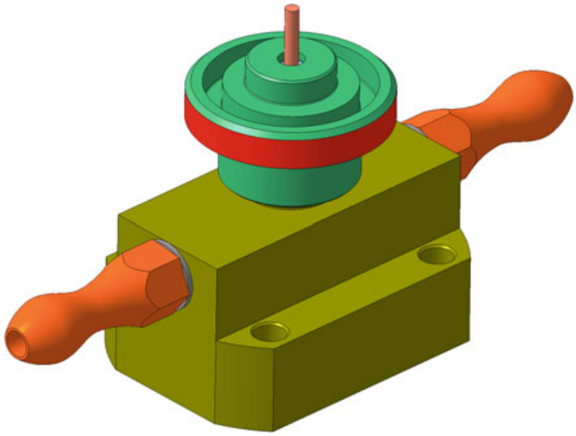
Item	Part name	Quantity
Parts		
1	Valve	1
2	Valve seat	1
3	Filler	1
4	Push-rod	1
5	Spring	1
6	Body	1

5.14 Exercise 13—Pneumatic Cylinder

Brief Description of the Product. Pneumatic cylinders (Figs. 5.37 and 5.38) are used as a power link in fixtures and drive mechanisms of clamping devices. They use compressed air. Pneumatic cylinders provide remote adjustment and control of the clamping force and are characterized by fast action. The large piston area (with a diameter of 80 mm) allows you to get significant forces at low pressure.

The list of components of the pneumatic cylinder (Fig. 5.39) is specified in Table 5.13.

Fig. 5.34 Pneumatic reducing valve (assembly view)



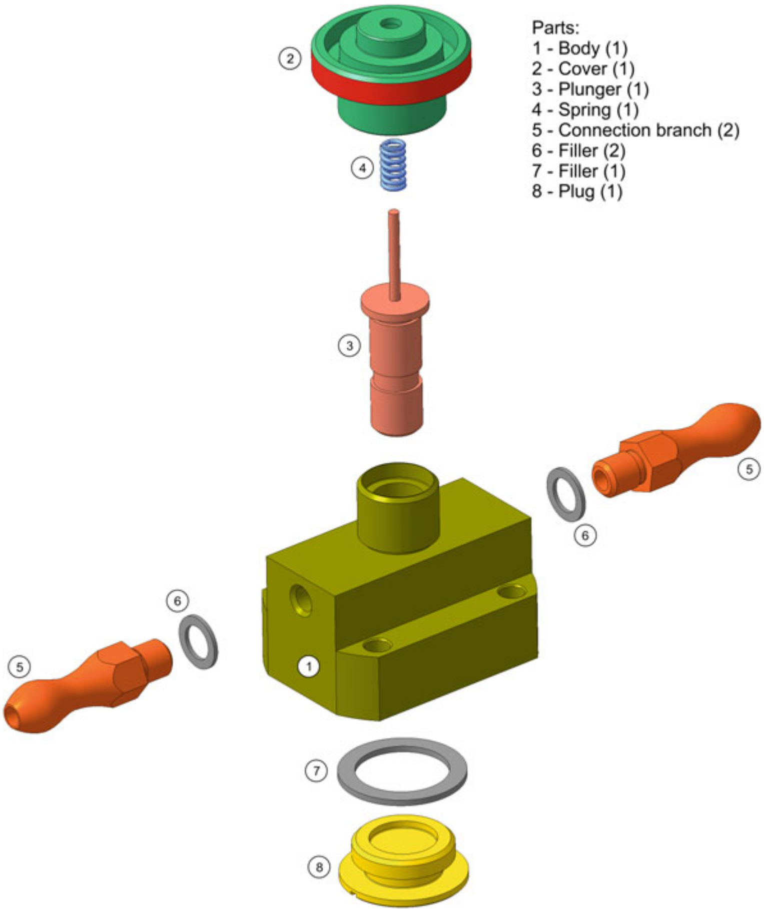


Fig. 5.35 Pneumatic reducing valve (exploded view)

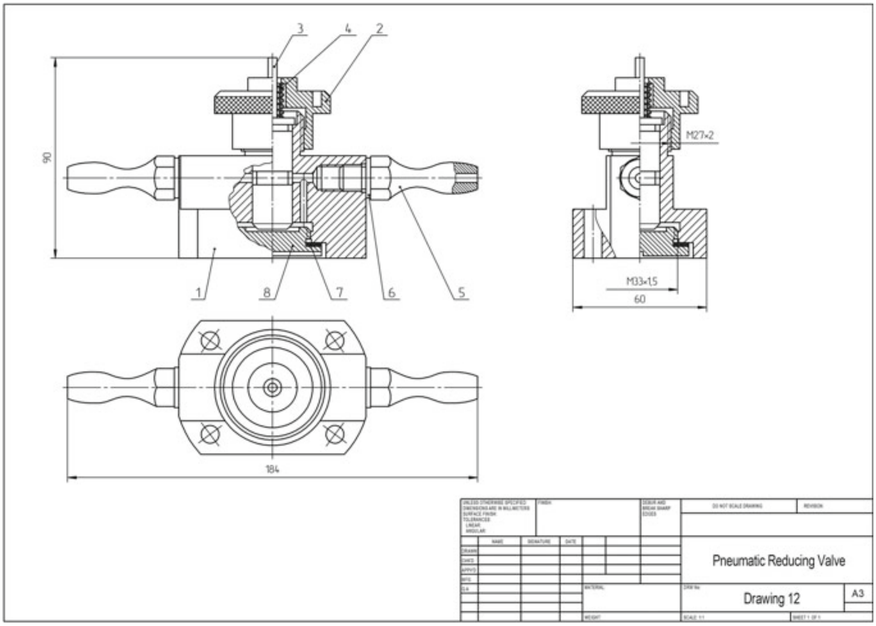


Fig. 5.36 Pneumatic reducing valve (drawing)

Table 5.12 Parts list

Item	Part name	Quantity
Parts		
1	Body	1
2	Cover	1
3	Plunger	1
4	Spring	1
5	Connecting branch	2
6	Filler	2
7	Filler	1
8	Plug	1

5.15 Exercise 14—Sliding V-Block

Brief Description of the Product. The sliding V-block (Fig. 5.40) serves as a fixed support when machining parts with a diameter of 40–200 mm on drilling, boring, milling, and planning machines. It consists of body 1 (Fig. 5.41), which is fixed relative to the tool with keys (the key is not shown in the drawing) and fixed with machine tool bolts. Prismatic jaw members 2 and 3 are moved along the body guides by rotating screw 4 (with right and left threads).

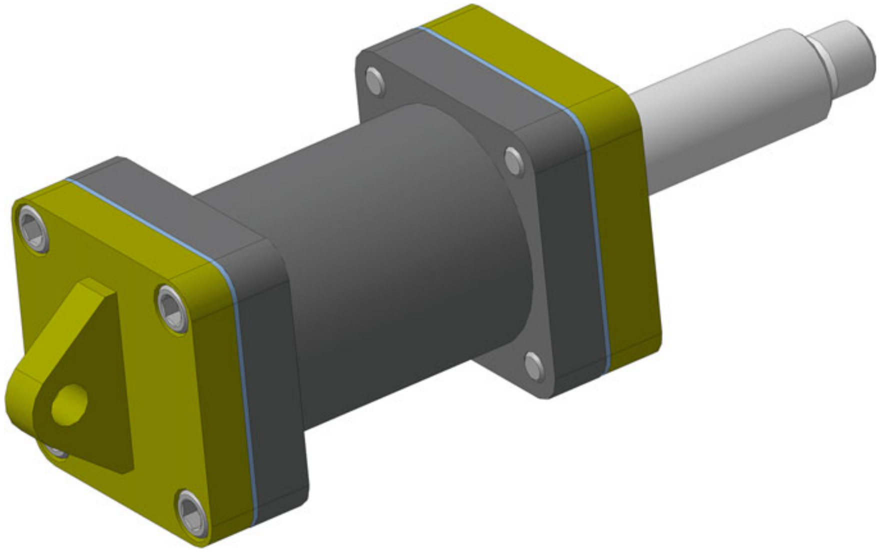


Fig. 5.37 Pneumatic cylinder (assembly view)

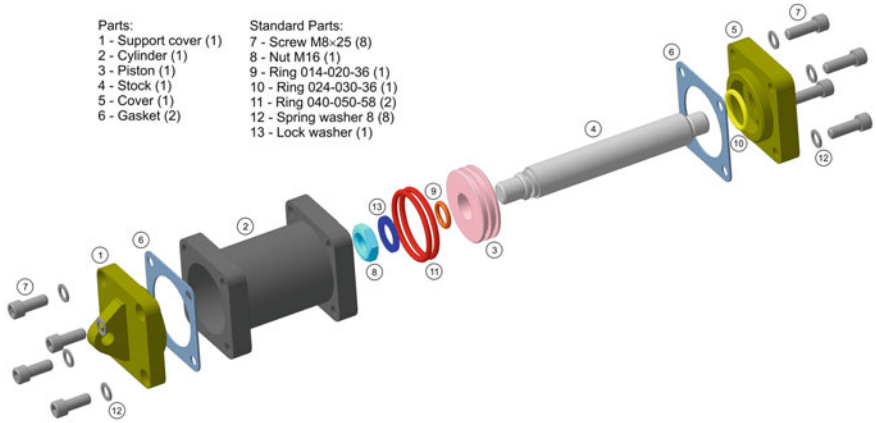


Fig. 5.38 Pneumatic cylinder (exploded view)

The list of components of the sliding V-block (Fig. 5.42) is specified in Table 5.14.

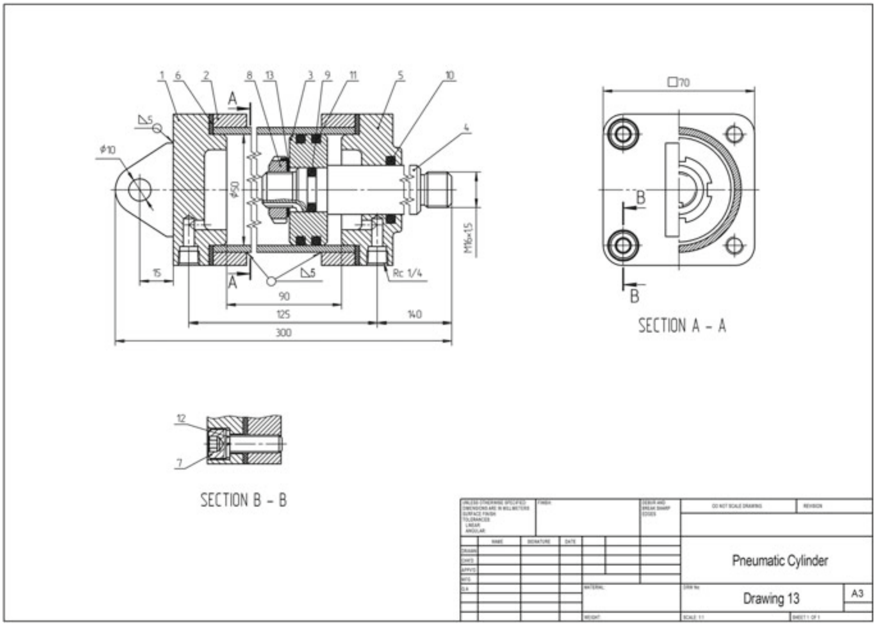


Fig. 5.39 Pneumatic cylinder (drawing)

Table 5.13 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			Standard parts		
1	Support cover	1	7	Screw M8 × 25	8
2	Cylinder	1	8	Nut M16	1
3	Piston	1	9	Ring 014-020-36	1
4	Stock	1	10	Ring 024-030-36	1
5	Cover	1	11	Ring 040-050-58	2
6	Gasket	2	12	Spring washer 8	8
			13	Lock washer 16	1

5.16 Exercise 15—Milling Fixture

Brief Description of the Product. The fixture (Fig. 5.43) is used to quickly and accurately set the workpiece in the desired position concerning the cutting tool (milling cutter). The fixture is installed on the movable table of the horizontal milling machine and is attached to it with two bolts (the bolts are not shown in the drawing) included in the grooves of plate 1 (Fig. 5.44).

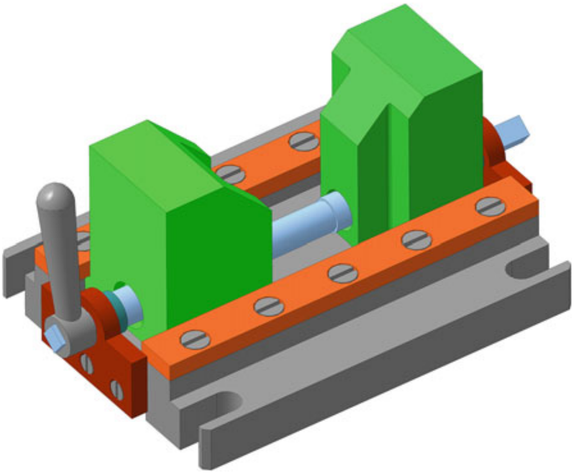


Fig. 5.40 Sliding V-block (assembly view)

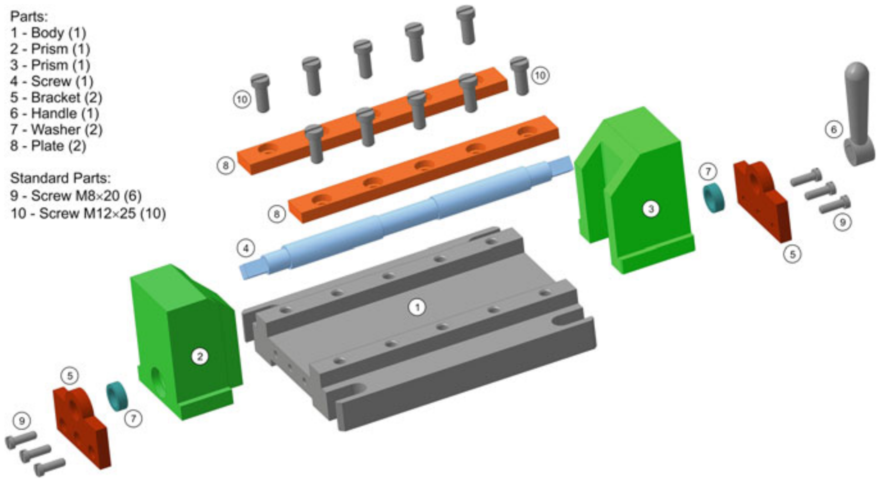


Fig. 5.41 Sliding V-block (exploded view)

The workpiece of the "lever" type (shown in the drawing as a solid thin line) is placed on the support plane of the slider 2. The position of the workpiece is fixed with pin 4, on which it is clamped with a clamp 5 on one side and a V-block 3 moved by a screw 6 on the other side. The slider is fixed in the desired position with screws 9.

The list of components of the milling fixture (Fig. 5.45) is specified in Table 5.15.

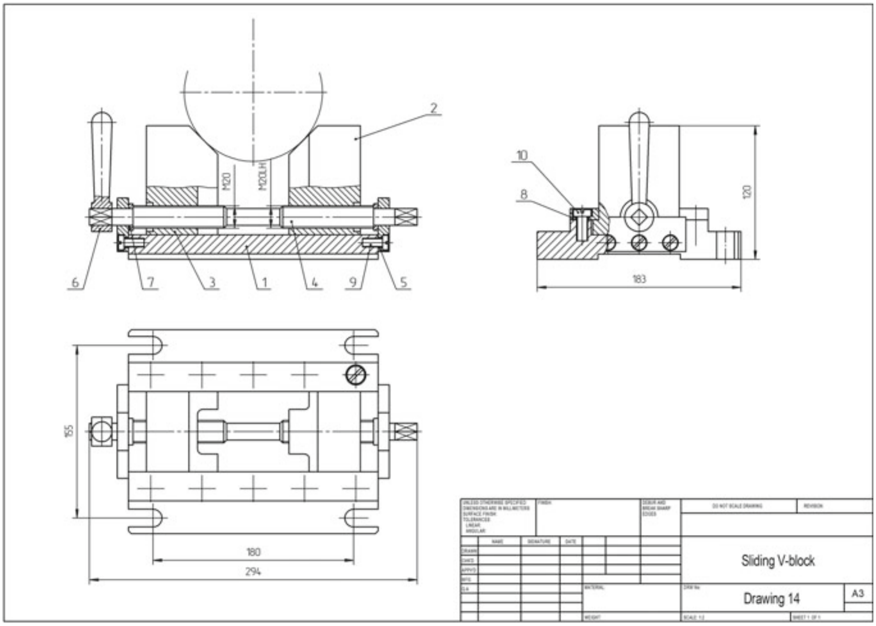


Fig. 5.42 Sliding V-block (drawing)

Table 5.14 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			Standard parts		
1	Body	1	9	Screw M8 × 20	6
2	Prism	1	10	Screw M12 × 25	10
3	Prism	1			
4	Screw	1			
5	Bracket	2			
6	Handle	1			
7	Washer	2			
8	Plate	2			

5.17 Exercise 16—Locking Device

Brief Description of the Product. The end locking device (Fig. 5.46) is designed to connect the ends of the hoses when bypassing compressed air from one container to another.

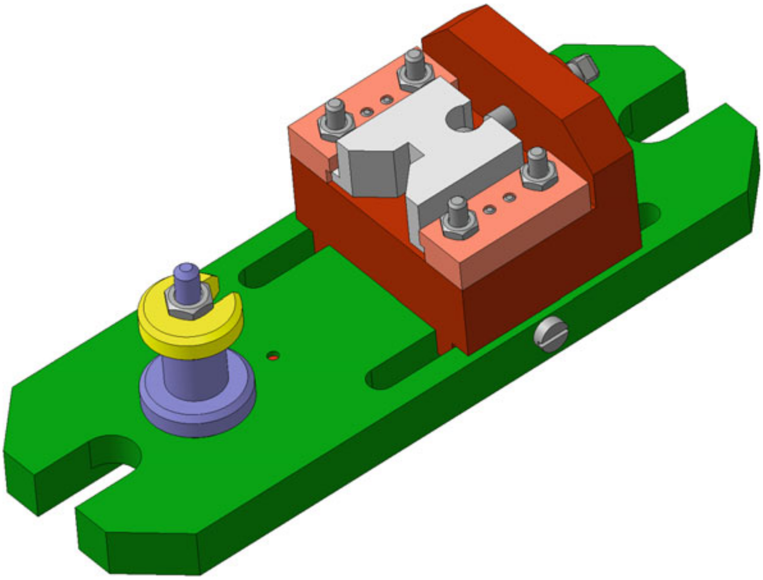


Fig. 5.43 Milling fixture (assembly view)

When connecting the ends of the hoses with a union nut 7 (Fig. 5.47), the balls 10 are squeezed out from the valve seat and the body, thereby opening the air passage. When the ends of the hoses are separated, the balls under the action of the spring 6 and air pressure tightly close the outlet openings of both ends.

The list of components of the locking device (Fig. 5.48) is specified in Table 5.16.

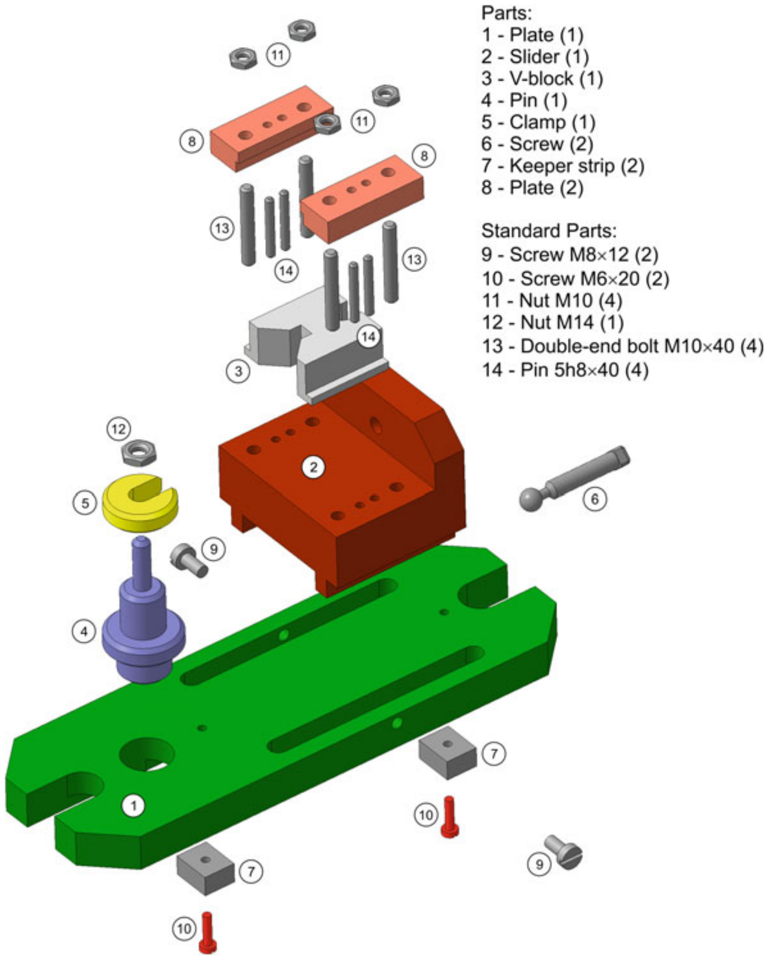


Fig. 5.44 Milling fixture (exploded view)

5.18 Exercise 17—Roller

Brief Description of the Product. This roller (Fig. 5.49) design is installed on the metal structures of the lifting transport mechanism and serves to guide the steel cable.

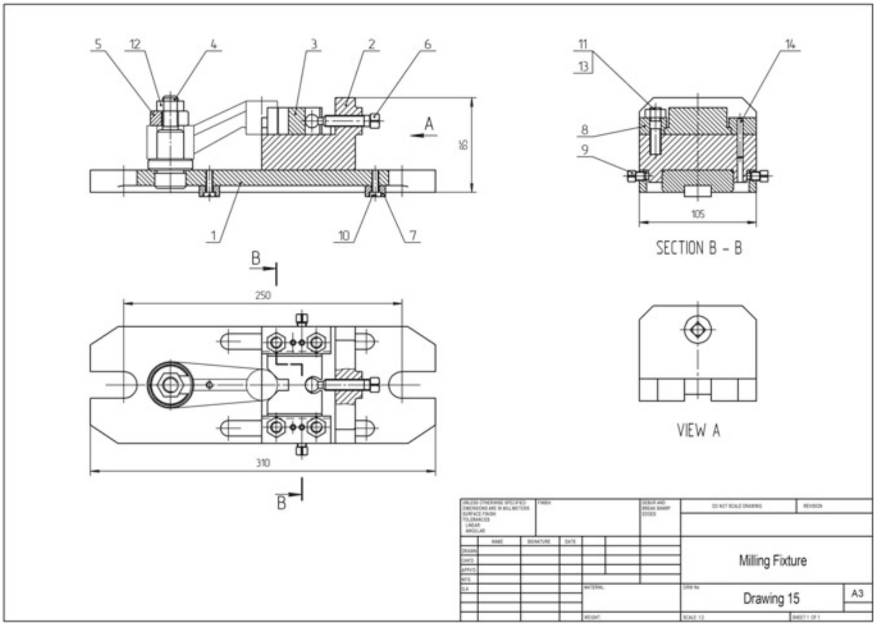


Fig. 5.45 Milling fixture (drawing)

Table 5.15 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			Standard parts		
1	Plate	1	9	Screw M8 × 12	2
2	Slider	1	10	Screw M6 × 20	2
3	V-block	1	11	Nut M10	4
4	Pin	1	12	Nut M14	1
5	Clamp	1	13	Double-end bolt M10 × 40	4
6	Screw	1	14	Pin 5h8 × 40	4
7	Keeper strip	2			
8	Plate	2			

The cable enters the groove of roller 3 (Fig. 5.50) and bends around the roller at a certain angle. The roller rotates freely on pin 5, which is fixed in the lugs of fork 2 by plate 7, which is included in the pin slot. Plate 7 is connected to fork 2 with two screws 10. To reduce friction during the rotation of the roller, an oiler is installed in the threaded hole of pin 5, from which lubricant flows through the cylindrical channels to the friction surfaces. Fork 2 is connected to bearing slide 4 with bolts 9 and nuts 12. Bearing slide 4 with fork 2 is fixtured with bolts 8 and nuts 11 on bracket

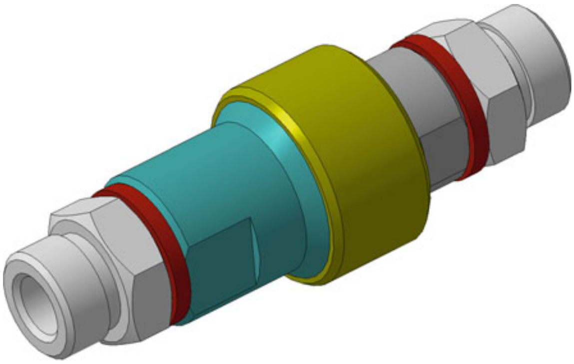


Fig. 5.46 Locking device (assembly view)

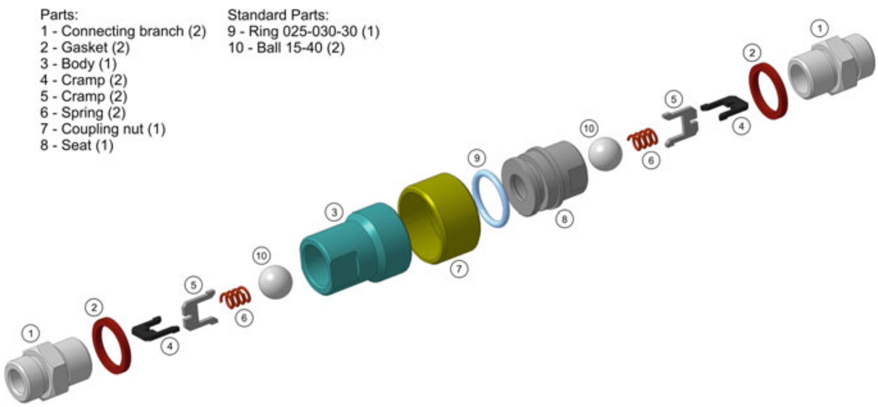


Fig. 5.47 Locking device (exploded view)

1. Bolts 8 and 9 can move along the grooves of parts 1 and 2, which is necessary when adjusting the position of the roller.

The list of components of the roller (Fig. 5.51) is specified in Table 5.17.

5.19 Exercise 18—Tension Roller

Brief Description of the Product. The tension roller (Fig. 5.52) is designed for tensioning belts in V-belt drives.

The base of the roller is frame 1 (Fig. 5.53), fixed with 12 bolts at the installation site. Two ball bearings 14 are installed on the cylindrical part of slider 3, on which roller 2 rotates freely. The slider moves in the guide grooves of the frame by screw 9. When the screw rotates, nut 7 acts on the slider through spring 10.

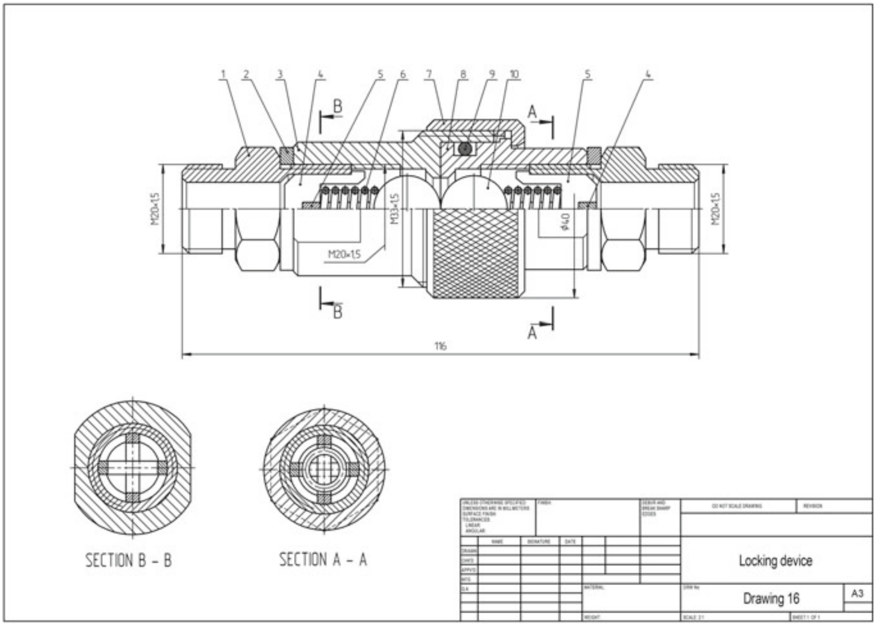


Fig. 5.48 Locking device (drawing)

Table 5.16 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			Standard parts		
1	Connecting branch	2	9	Ring 025-030-30	1
2	Gasket	2	10	Ball 15–40	2
3	Body	1			
4	Cramp	2			
5	Cramp	2			
6	Spring	2			
7	Coupling nut	1			
8	Seat	1			

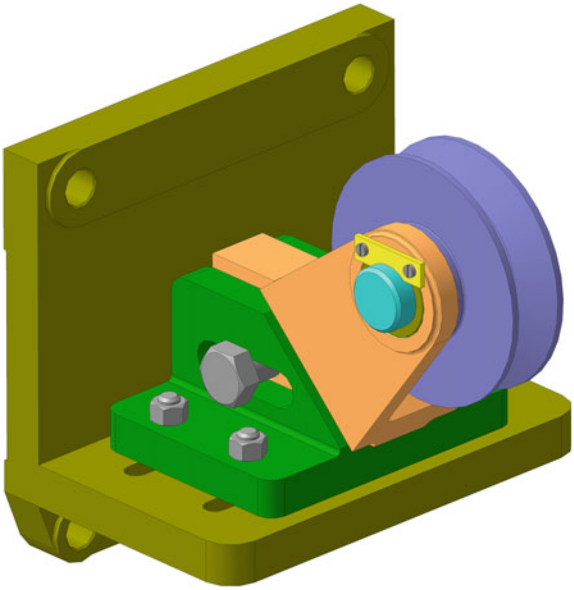


Fig. 5.49 Roller (assembly view)

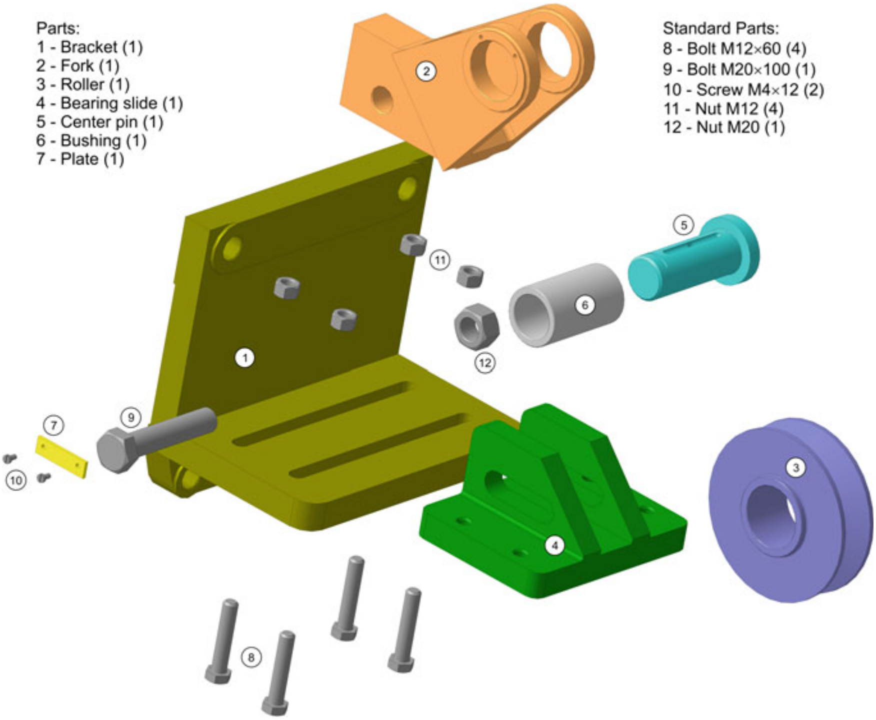


Fig. 5.50 Roller (exploded view)

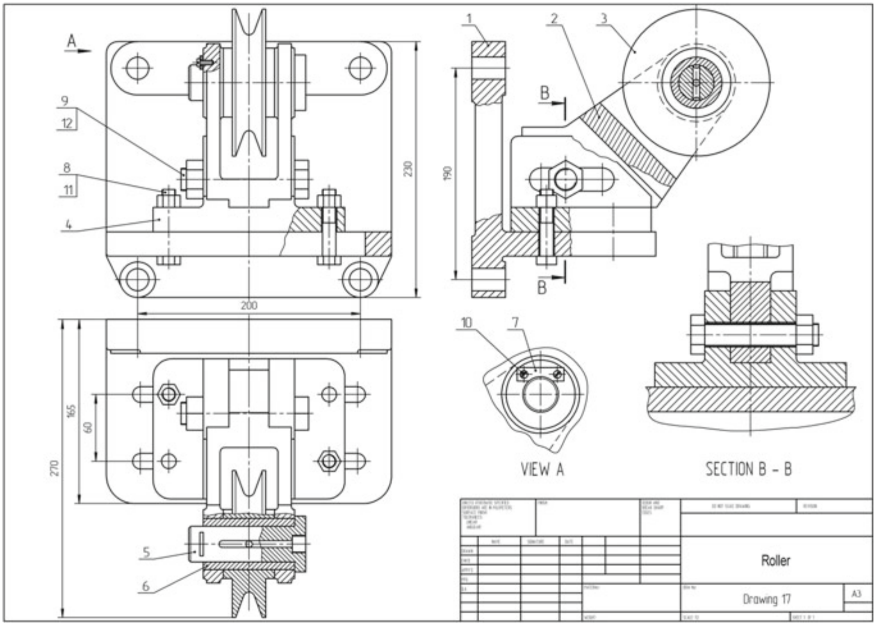


Fig. 5.51 Roller (drawing)

Table 5.17 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			Standard parts		
1	Bracket	1	8	Bolt M12 × 60	4
2	Fork	1	9	Bolt M20 × 100	1
3	Roller	1	10	Screw M4 × 12	2
4	Bearing slide	1	11	Nut M12	4
5	Center pin	1	12	Nut M20	1
6	Bushing	1			
7	Plate	1			

The list of components of the tension roller (Fig. 5.54) is specified in Table 5.18.

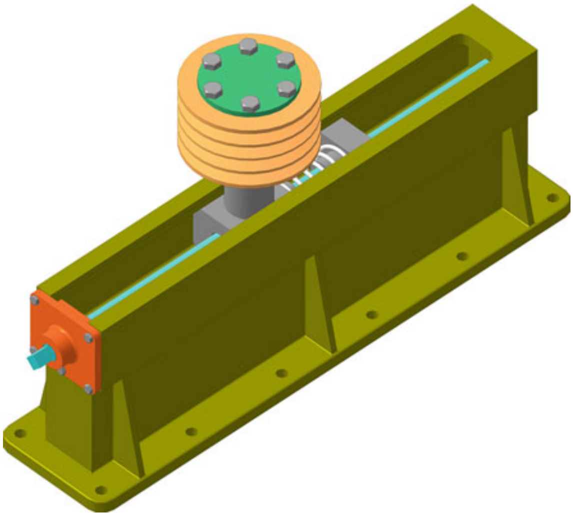


Fig. 5.52 Tension roller (assembly view)

5.20 Exercise 19—Supporting Roller

Brief Description of the Product. The rollers (Fig. 5.55) are installed on the sheet rolling mill on both sides to support the rolled sheets while feeding and receiving them from the rolls.

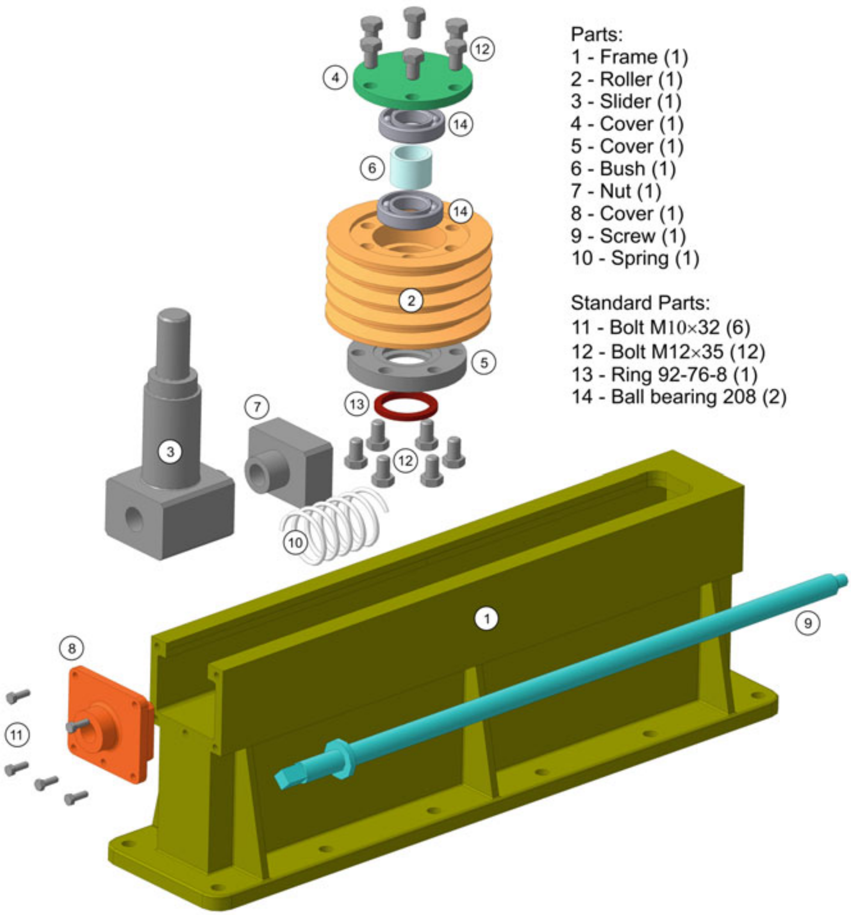


Fig. 5.53 Tension roller (exploded view)

The roller is driven by an electric motor. Shaft 7 (Fig. 5.56) is supported by rolling bearings 14. The bearings are lubricated with grease coming from oilers pressed into the holes of the covers 3. The roller bodies 1 are bolted to the frame of the rolling mill.

The list of components of the supporting roller (Fig. 5.57) is specified in Table 5.19.

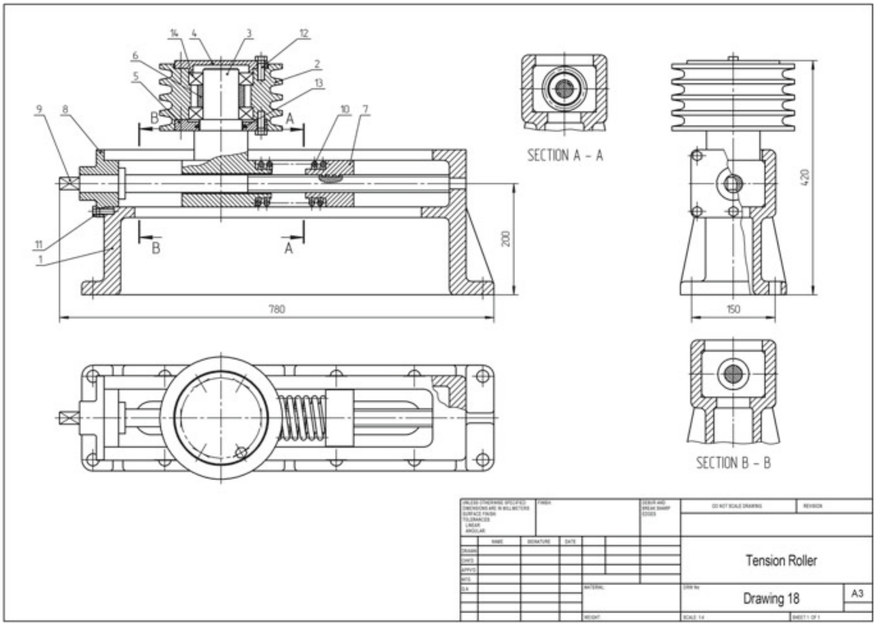


Fig. 5.54 Tension roller (drawing)

Table 5.18 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			Standard parts		
1	Frame	1	11	Bolt M10 × 32	6
2	Roller	1	12	Bolt M12 × 35	12
3	Slider	1	13	Ring 92-76-8	1
4	Cover	1	14	Ball bearing 208	2
5	Cover	1			
6	Bush	1			
7	Nut	1			
8	Cover	1			
9	Screw	1			
10	Spring	1			

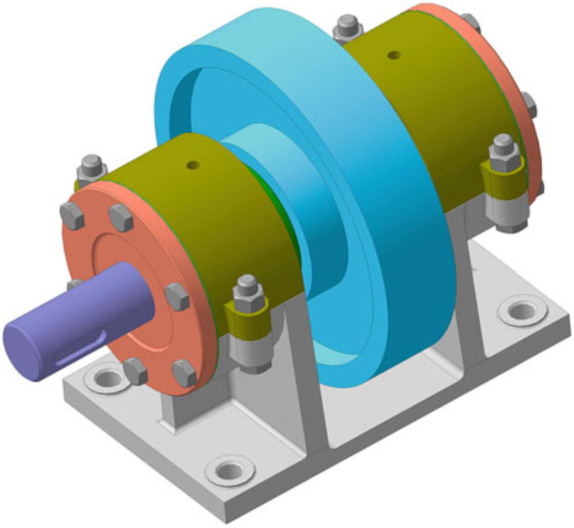


Fig. 5.55 Supporting roller (assembly view)

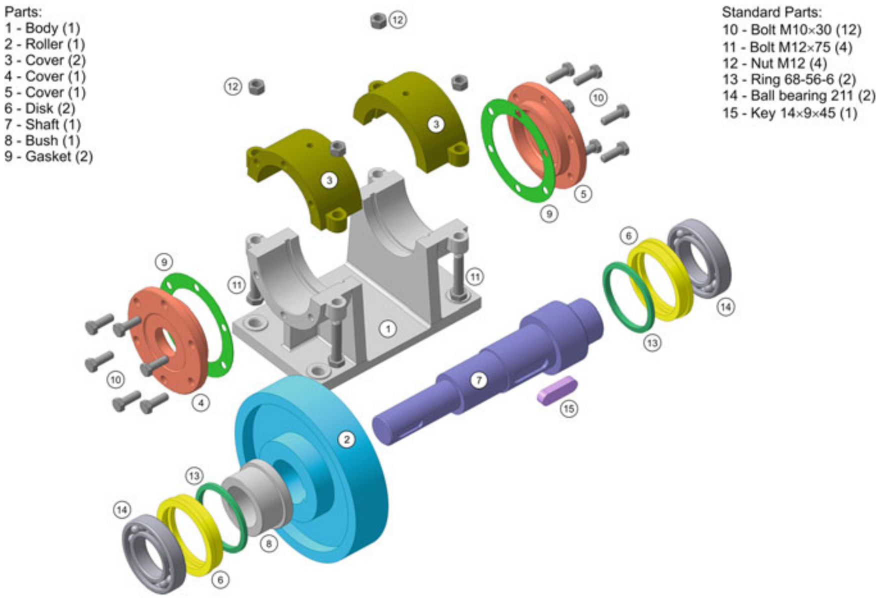


Fig. 5.56 Supporting roller (exploded view)

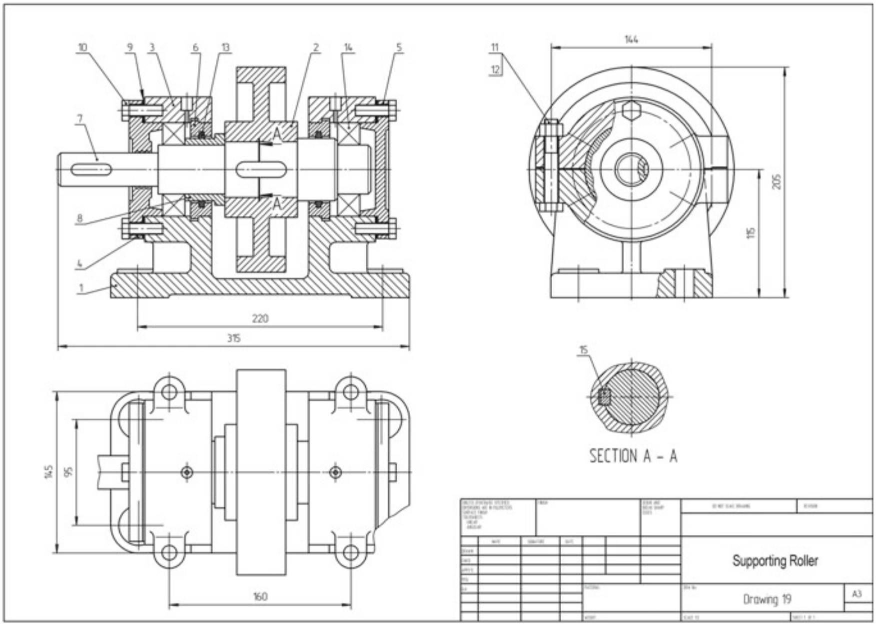


Fig. 5.57 Supporting roller (drawing)

Table 5.19 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			Standard parts		
1	Body	1	10	Bolt M10·30	12
2	Roller	1	11	Bolt M12·75	4
3	Cover	2	12	Nut M12	4
4	Cover	1	13	Ring 68-56-6	2
5	Cover	1	14	Ball bearing 211	2
6	Disk	2	15	Key 14·9·45	1
7	Shaft	1			
8	Bush	1			
9	Gasket	2			

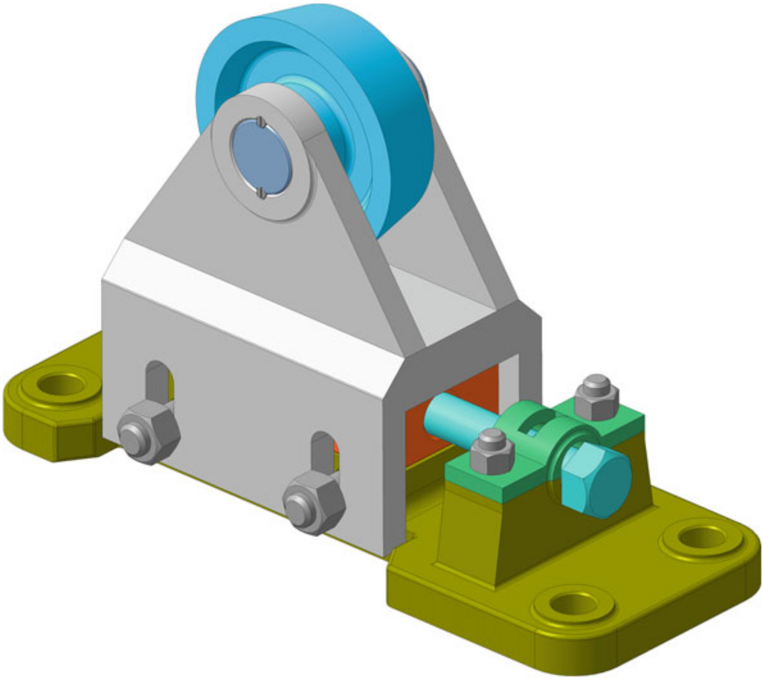


Fig. 5.58 Adjustable roller (assembly view)

5.21 Exercise 20—Adjustable Roller

Brief Description of the Product. The roller device (Fig. 5.58) is used when transporting sheet material, which rolls over rollers.

Body 1 (Fig. 5.59) is attached to the machine's frame with four bolts (the frame and bolts are not shown in the drawing).

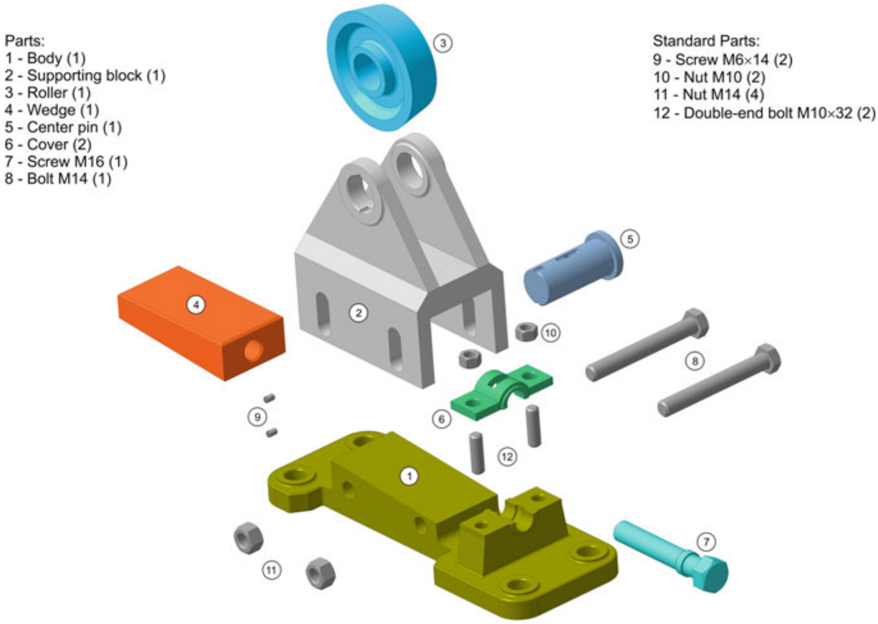


Fig. 5.59 Adjustable roller (exploded view)

When screw 7 is rotated, wedge 4 will slide along the inclined plane of the body. As a result, the supporting block 2 with roller 3 will rise or fall. After installing the roller at the desired level, the supporting block is fixed with bolts 8 and nuts 11. The roller rotates on center pin 5, which is fixed on the supporting block with screws 9.

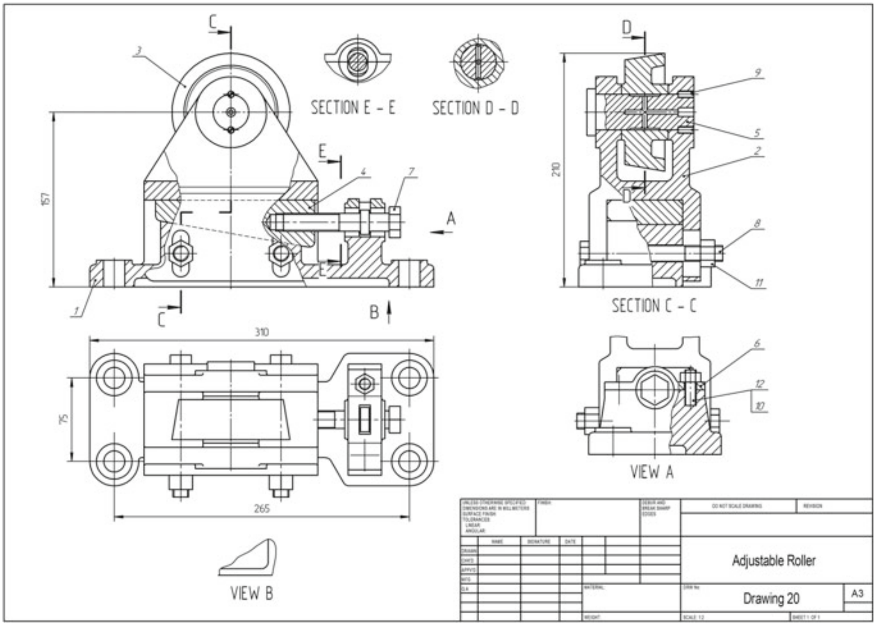


Fig. 5.60 Adjustable roller (drawing)

Table 5.20 Parts list

Item	Part name	Quantity	Item	Part name	Quantity
Parts			Standard parts		
1	Body	1	9	Screw M6 × 14	2
2	Supporting block	1	10	Nut M10	2
3	Roller	1	11	Nut M14	4
4	Wedge	1	12	Double-end bolt M10 × 32	2
5	Center pin	1			
6	Cover	1			
7	Screw M16	1			
8	Bolt M14	2			

To the rubbing surfaces of the roller and the pin through the holes and special grooves in the axle comes thick grease from the oiler. The oiler is pressing into the center pin hole 5 (not shown in the drawing).

The list of components of the adjustable roller (Fig. 5.60) is specified in Table 5.20.

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