Innovation Ability Training Mode of Postgraduates in the Mechanical Discipline Based on Simulation Technology

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Abstract—The innovation ability of mechanical discipline graduate students in China is trained mainly through classroom teaching and scientific research. Theoretical knowledge is traditionally passed on to students in class by "spoon-feeding," which makes the learning process boring. Scientific research combines theoretical knowledge with experiment. However, its experimental condition and experimental equipment requirements are high. The experimental resources in many universities can hardly satisfy the requirements, seriously hindering the cultivation of the innovation ability of postgraduates. Therefore, this study proposes a new approach to enhancing the innovation ability of postgraduates in the mechanical discipline based on simulation technology, describes the positive role of simulation technology in the training process, and takes the wavy lip seal as an example to illustrate the application of simulation technology in enhancing innovation ability in detail. The comparison of the traditional and new training modes shows that the innovation ability of postgraduates in the mechanical discipline improves considerably when the new training mode is adopted. Furthermore, the new training mode is recognized by graduate students and enterprises.

Keywords—Simulation technology, Innovation ability, Postgraduates in mechanical discipline, Training mode

1 Introduction

A growing demand for innovative talents is observed with the rapid economic and technology development in China. Postgraduate education is an important venue for enhancing innovative talents [1]. Specifically, postgraduate education in the mechanical discipline is an important part of the postgraduate education in China.

Currently, the innovation ability of postgraduates in the mechanical discipline is mainly cultivated through classroom teaching and scientific research. Classroom teaching mainly combines textbooks and courseware and adopts the spoon-feeding mode, which makes the learning process dull. This teaching process results in unintuitive teaching content, low student enthusiasm, and low improvement rate in terms of the initiative and creativity of postgraduates. Scientific research is a combination of theoretical research and experiment, including subject research, participating in innovation competitions, and publishing academic papers. However, experimental resources in many universities are relatively insufficient. Consequently, theoretical research results cannot be verified in a timely manner, and many existing experiments are to verify the existing theoretical knowledge. In addition, many experiments need high experimental condition, environment, and equipment requirements. Existing experimental resources can hardly satisfy these requirements, thereby limiting the improvement of the initiative and innovation ability of postgraduates. Simulation technology is a comprehensive technology that uses computers and is safe, efficient, and parameters can be changed easily; this technology is widely used in mechanical research, design, and production process [2]. Postgraduates can use simulation technology to verify theoretical research results, obtain different solutions to a problem, and develop an appropriate system according to the research direction, subject requirements, and interests. Simulation technology is beneficial for enhancing the creativity and innovative consciousness of postgraduates. However, simulation technology is rarely combined with cultivating the innovation abilities of postgraduates in the mechanical discipline in China. Therefore, the application of simulation technology to improve the innovation abilities of postgraduates in the mechanical discipline is a problem of educators that should be resolved urgently.

2 State of art

Innovative talents are the key to building an innovative country, and postgraduates are the main pool of creative talents; the level of postgraduate innovation ability affects the innovation ability of the entire country, and the improvement of the creativity of graduate students is the need of economic and social development in the 21st century [3, 4]. Mechanical discipline is one of the most comprehensive and practical subjects, and innovation ability cultivation is important in postgraduate education in the mechanical discipline. Teixeira et al. [5] proposed the task of postgraduates in the mechanical discipline is to carry out technological innovations. Consequently, many educational scholars at home and abroad have investigated how to improve the innovation abilities of postgraduates in the mechanical discipline. Gu et al. [6] transformed the scientific research results of the National Natural Science Project into the experimental teaching content for postgraduates in the mechanical discipline by constructing a professional comprehensive experimental platform for cultivating the innovation abilities of postgraduates. However, this training mode is only suitable for colleges and universities with abundant teaching resources, and universities with lacking experimental equipment have considerable limitations. Zhang et al. [7] explored a training method that forms systemic knowledge and skills by strengthening the mastered knowledge and combining theoretical knowledge with engineering practice, but the method is not applicable to graduate projects because it requires rigorous laboratory conditions and expensive facilities.

Breakthroughs have been made in digital simulation technology with the development of computer technology. Merticaru [8] and Kabouridis [9] introduced the role of advanced CAD/CAM/CAE fusion simulation technology in the mechanical discipline undergraduate courses and large integrated engineering in detail, respectively. However, the application of simulation technology in postgraduate courses and scientific research has not been extensively explored. Chowdhury et al. [10] reported that computer simulation technology is applied to the teaching, research, and practice of postgraduates in the mechanical discipline to improve their design technology knowledge and equip them with multi-disciplinary skills. Practice has proven that simulation technology plays a guiding role in cultivating the exploration and innovation ability of postgraduates. Nevertheless, the application of simulation technology to train the innovation abilities of postgraduates is not elucidated. Valiulis [11] suggested that modeling and simulation technology are used in the study of materials and welding engineering to estimate the influence of different surfacing layers and volume forces on liquid metal convection in molten pool and proposed that the mechanical engineering practice laboratory can be replaced by various simulation technologies to perform simulation experiments. However, the application of simulation technology in graduate training is one-sided.

To improve the innovation abilities of postgraduates in the mechanical discipline, a new training mode that integrates simulation technology is presented in this study. The model does not only address the shortcomings of traditional training methods and improve the innovation ability of postgraduates but also enable postgraduates to master simulation technology in the research process for future studies and works.

3 Methodology

Simulation technology is a comprehensive computer-aided technology that mainly includes computer modeling, manufacturing, and engineering. Computer-aided modeling can be used for 2D and 3D geometric modeling, drawing, and design of mechanical products. Commonly used software contains Pro-E, UG, and SolidWorks. The main function of computer-aided manufacturing is to simulate the process of processing and assembly, for which Edgecam and Mastercam software are often used. Computer-aided engineering can simulate the working process of products according to the actual working conditions. Such as Moldflow, ANSYS, Polyflow, and other software are usually used. In addition, software and systems can be developed on the basis of the research object requirements.

Adding simulation technology into postgraduate classes can make the teaching content concrete and intuitive through pictures or videos and arouse the learning interest of students. In addition, teachers should guide and encourage students to take full advantage of the simulation technology to detect, analyze, and solve problems during scientific research.

During the design process, postgraduates can change the model shape and the design results any time. The results of each modification can be saved to facilitate reuse during the design process. The study objects can become intuitive through computer modeling and serve as references for follow-up research. The objects are processed and assembled by postgraduates through CAM, which has a variety of machining methods and tools for different research requirements. In addition, postgraduates can use CAE to analyze research objects through changing object structures and working parameters and conditions, and the simulation process can be monitored real time. The simulation technology can not only preliminarily verify the results of theoretical research and experiments but also enable postgraduates to detect problems in the research process. The new method of the innovation abilities training of postgraduates in the mechanical discipline is shown in Fig. 1.

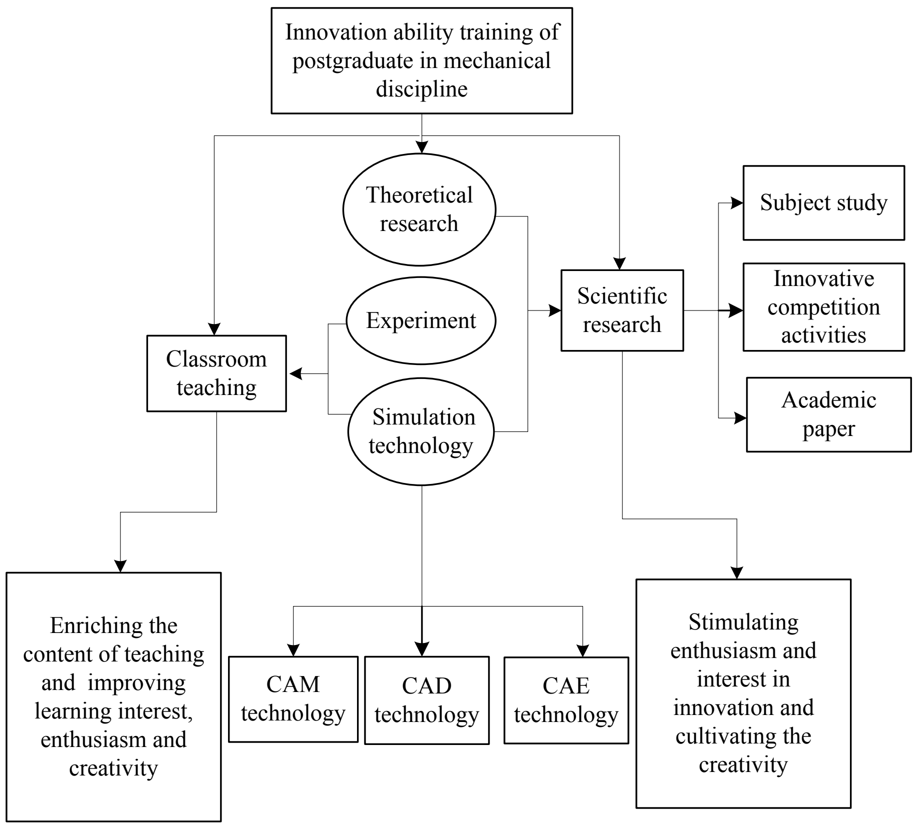

Fig. 1. New method of cultivating the innovation ability of postgraduates in the mechanical discipline

4 Teaching case and effectiveness

4.1 Teaching case

Taking the wavy lip seal as an example, the application of the simulation technology to train the innovation abilities of postgraduates in the mechanical discipline is illustrated in detail.

In a wavy lip seal, the heat in the contact area is reduced by 25%–30% compared with the ordinary lip seals, thereby reducing the premature failure of the seal caused by cracking from overheat, foaming, hardening, and oil film cracking, and the service life is increased by at least 30%. Owing to the wavy lip seal has complex free surfaces, and the design and manufacture of parts with these surfaces are difficult so that the wavy lip oil seal has excellent sealing and lubrication performance, but it has not been widely applied. Consequently, postgraduate study on sealing mechanism, design, and manufacture of wavy lip seal, which can solve the accurate design of the wavy lip seal, and the research results are highly important to improve mechanical seal and related technical. However, the shape of the wavy lip seal is difficult to describe for postgraduates using traditional modeling methods. Furthermore, numerous experiments are necessary to study the sealing performance of wavy lip seals, such as detecting the lip contact force, temperature, stress distribution, leakage, and durability experiments, and the equipment and condition requirements of these experiments are high. The existing teaching condition can hardly satisfy these requirements. Therefore, several instructors guide the postgraduates in adopting simulation technology in their study of wavy lip seals.

The postgraduates are guided in designing the wavy lip seal through CAD to supply the defects of the original design method. A 3D model of the wavy lip seal is required to observe the design result intuitively. The wavy lip seal model is difficult to build directly through the CAD software. Thus, the postgraduates are guided to study the circumferential unroll and roll transform algorithm, and develop the software based on this algorithm. Then, the 3D wavy lip seal model is combined with the CAD software as shown in Fig. 2.

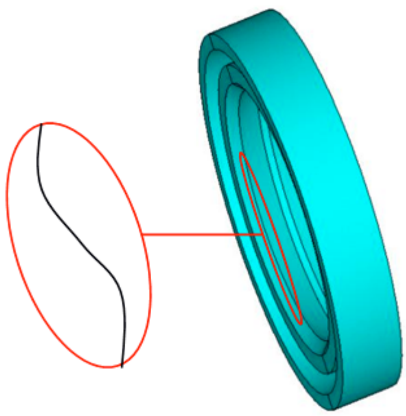

Fig. 2. 3D model of the wavy lip seal

The leakage and service life which are related to contact force, equivalent stress, lip temperature, and oil film thickness are the important indexes for evaluating the sealing performance of the wavy lip seal. The lip contact force, equivalent stress, lip temperature, and oil film thickness should be measured for studying the sealing performance of wavy lip seals. However, these experiments demand high experimental conditions, the experimental cycle is long, and the experimental cost is high. Teachers can instruct students to build the model of the wavy lip seal in the CAD software and import the model into the CAE software to conduct static and dynamic simulation analyses. The size and distribution of lip contact force, equivalent stress, lip temperature, and oil film thickness are investigated according to the simulation results. For example, the contact pressure and the equivalent stress of the wavy lip seal are shown in Figs. 3 and 4, respectively.

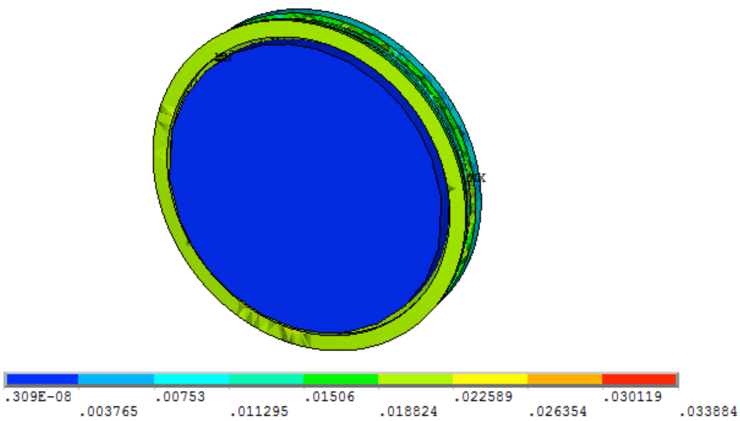

Fig. 3. Contact pressure distribution of the wavy lip seal

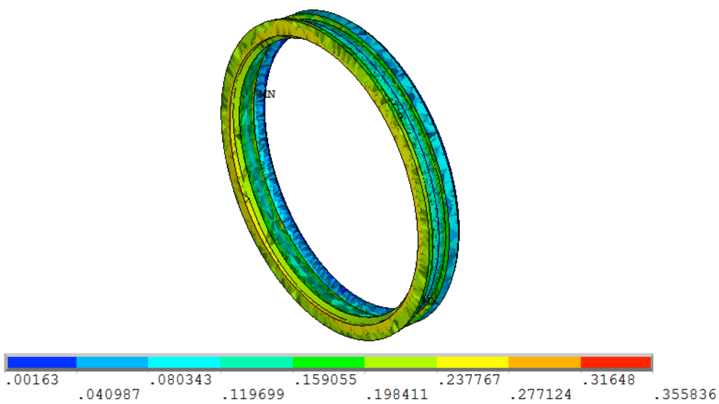

Fig. 4. Equivalent stress distribution of the wavy lip seal

The sizes and distributions of the contact pressure and equivalent stress of the wavy lip seal are shown in Figs. 3 and 4 respectively. The structure design of the wavy lip seal can be optimized and the sealing mechanism can be investigated according to the sizes and distributions of contact pressure and equivalent stress.

Teachers should guide the postgraduates into thinking and discussing different solutions to the problem, analyzing the shortcomings of the method, and realizing the optimum solution and research methods through simulation technology. Postgraduates can verify their creative ideas by using simulation technology and changing the system structure and design parameters to design an appropriate program. This practice is beneficial for stimulating the enthusiasm and training the creativity of postgraduates. Simulation technology lays the foundation for the experiment, reduces the experiment cost, and shortens the experiment time. In addition, simulation can replace experiment to compensate for the shortage of teaching resources in several colleges and universities.

4.2 Effectiveness

Two academic postgraduate classes of 2014 are marked as class A and class B according to the actual training situation in the mechanical discipline of our university. Class A continued to implement traditional training, while class B adopted the new training mode. The percentage of scientific research results, the ratio of innovation competitions, and the theses of postgraduates in class A and class B are summarized after three years of study. In addition, a questionnaire survey about the degree of interest in the subject and the satisfaction with the training mode was answered by graduate students of class A and class B. Moreover, a questionnaire survey on the satisfaction degree of employers of students in class A and class B was conducted. The survey results are shown in Fig. 5.

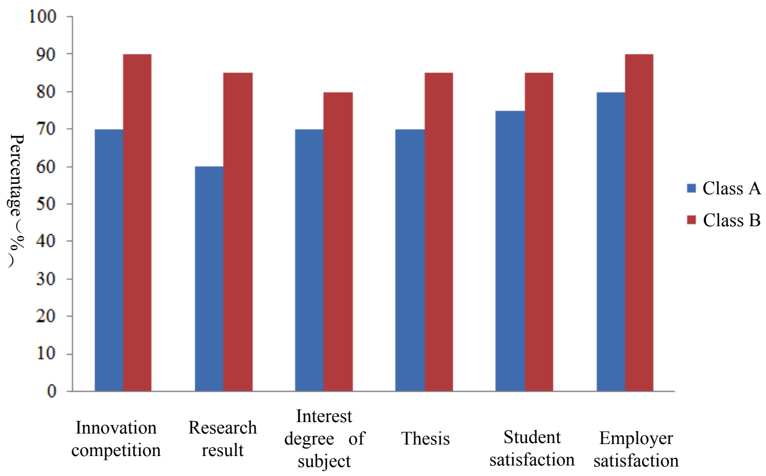

Fig. 5. Survey results

Class B is higher than class A in all indices as shown in Fig. 5. Simulation technology can stimulate the innovative thinking and improve the innovative consciousness and innovation ability of postgraduates. Moreover, the application of simulation technology to postgraduate education can stimulate the interest and enthusiasm of students. The employer satisfaction index shows that the postgraduates who were trained with the new training mode can satisfy the requirements of employers.

5 Conclusions

This study proposed a new training mode for improving the innovation abilities of postgraduates in the mechanical discipline based on simulation technology and introduced the importance of simulation technology to the training mode. Taking the wavy lip seal as an example, the application of simulation technology in graduate research was elucidated in detail. A questionnaire survey was conducted to evaluate the new training mode for postgraduates. Results showed that the new training mode can address the shortcomings of the traditional training mode, which can be concretely enumerated as follows:

1. Simulation technology is integrated into graduate scientific research, which can compensate for the shortages of experimental facilities in colleges and universities. Postgraduates can design, model, process, and analyze mechanisms using computer simulation technology.
2. Integrating simulation technology into graduate classroom teaching can stimulate the interest and enthusiasm of postgraduates and improve their initiative and creativity.
3. Postgraduates in the mechanical discipline can develop corresponding systems according to their interests, which can not only provide a technical basis for their research, but also help to cultivate the innovative abilities of postgraduates and meet the requirements of enterprises for simulation talents.

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7 References

[1] C. N. Jing, Y. Li, S. H. Wang, L. S. Zhao, and S. B. Xu. Innovation and development of curriculum reform for postgraduate education of materials science and engineering, Applied Mechanics and Materials, 2014, vol. 631-632, pp. 1365-1369.
[2] D. Mourtzis, N. Papakostas, D. Mavrikios, S. Makris, and K. Alexopoulos. The role of simulation in digital manufacturing: applications and outlook, International Journal of Computer Integrated Manufacturing, 2015, vol. 28(1), pp. 3-24. https://doi.org/10.1080/0951192X.2013.800234
[3] A. F. M. Hani, L. Arshad, A. S. Malik, A. Jamil, and F. Y. B. Bin. 2011 National Postgraduate Conference-Energy and Sustainability: Exploring the Innovative Minds, NPC 2011. 3rd National Postgraduate Conference-Energy and Sustainability: Exploring the Innovative Minds, NPC 2011, 2011.
[4] Ian E. G. Davey-Wilson. Innovation in the building process — a postgraduate module, Engineering Structures, 2001, vol. 3(1), pp. 136-144.

[5] J. C. F. Teixeira, J. Ferreira, Da. Silva, and P. Flores. Development of mechanical engineering curricula at the University of Minho, European Journal of Engineering Education, 2007, vol. 32(5), pp.539-549. https://doi.org/10.1080/03043790701433210
[6] L. C. Gu, P. J. Liu, Y. Sun, and R. Xu. Construction and practice of comprehensive experimental platform of postgraduate students of mechanical engineering, Experimental Technology and Management, 2015, vol. 32(5), pp. 16-20.
[7] X. G. Zhang, and Y. P. Du. Exploration in the curriculum and teaching based cultivation of innovation capabilities for graduate students, Advanced Materials Research, 2013, vol. 655-657, pp. 2132-2135. https://doi.org/10.4028/www.scientific.net/AMR.655-657.2132
[8] V. Merticaru, G. Nagit, B. Pralea, and R. Oana. Convergent use of advanced CAD/CAE/CAM capabilities for sustainable integrated engineering, Academic Journal of Manufacturing Engineering, 2014, vol. 12(2), pp. 43-48.
[9] G. Kabouridis, G. L. Giannopoulos, and S. A. Tsirkas. On the development of course interconnections within a mechanical engineering training programme via single CAD/CAM/CAE software, World Transactions on Engineering and Technology Education, 2015, vol. 13(3), pp. 1-7.
[10] A. A. Chowdhury, and A. M. Mazid. Computer integrated manufacturing education to mechanical engineering students: Teaching, research and practice, 2009 IEEE International Conference on Industrial Technology, pp. 1-5.
[11] A. V. Valiulis. Teaching of Materials and Welding Engineering to Today's Postgraduate Mechanical Engineers, Solid State Phenomena, 2006, vol.113, pp. 625-628. https://doi.org/10.4028/www.scientific.net/SSP.113.625

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