Stands with a reusable diaphragm for the production of composites materials used in engineering industrial companies

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Abstracts. The article discusses the features of the stands with a reusable diaphragm use in technology development for engineering industrial companies (EIC). The main advantages of this solution are highlighted, as well as a comparison with the existing analogues. It is shown that the use of stands with a reusable diaphragm significantly increases the competence level, organizational and technological resources of the EIC, employed in the production of composite materials.

1. Article

One of the key areas of industrial growth today is new materials. Special attention should be paid to composite materials, because today it is already impossible to imagine the advanced technology production without their use. At the industrial development forefront today are engineering industrial companies that combine engineering, manufacturing and economic activities. The composite materials introduction is an undoubted object of interest for EICs, however, they face a serious problem of personnel lack. Human resources training is a task that needs to be solved not only by educational institutions, but also by EIC, enterprises, specialized competence centers, educational centers, etc. The most important stage in the competitive human resources formation is the hard competencies accumulation and development [1-4], for which it is necessary to use the appropriate equipment.

An equally important stage in the industry development is the transfer of competencies. EIC is an integral part of this process, since they allow you to quickly introduce advanced technical solutions. This is especially important in the case of composite materials, because often companies need to manufacture a small batch of composite structures, and it is impractical to implement a whole production line for this.

EIC can either independently make a small batch of the required products, or provide the customer with a ready-made solution that will allow him to independently manufacture this product.

In this regard, the issue of equipping the EIC with appropriate equipment, which allows not only to develop competencies, but also to ensure the possibility of manufacturing products in a small batch [5-6], arises. there must be a transfer of technologies, a transition to factories of the future and the introduction of new materials into industry. Special attention should be paid to the equipment users safety and the environmental friendliness of production.

Accordingly, the question of production technology arises. There are several technologies for the composite structures production, each of which allows the manufacture of a product of a certain geometry and a certain quality. Quality refers to the binder volume fraction. In the case of a polymer composite material, the lower the binder volume, the better the strength, mechanical and other material characteristics. In addition to the product characteristics, depending on the technology, the cost of the necessary technological equipment, consumables and auxiliary materials, as well as the requirements for the technologist qualifications, also change. The most accessible, both from a financial and a qualification point of view, is the contact molding technology. However, it is characterized by an extremely low quality of the parts obtained, as well as a relatively high production hazard, since application of the binder and its curing takes place in an open manner. The highest quality of the resulting composite products can be achieved using the autoclave molding technology, but an autoclave is a very expensive equipment, moreover, its use is often impossible due to safety standards [7]. The best quality and manufacturing cost ratio is possessed by the vacuum infusion technology [8], therefore it is rational to consider it for equipping EIC.

Among the current equipment on the market, there are three options that allow you to manufacture products by the vacuum infusion method and develop competencies with their help: «Young composite manufacturer set», reusable diaphragm training and demonstration stand, and traditional infusion equipment.

2. Comparative analysis of the presented solutions

When making a comparison, it is necessary to set the parameters to be analyzed. Considering that equipment for the formation of competencies is being considered, the cognitive part of the solutions, as well as the safety for users, are assessed first. «Young composite manufacturer set» is a set of tables, hand and power
tools, and equipment for teaching the parts from polymer composite materials manufacture. It assumes the use of standard consumables (vacuum films, sealing tapes, etc.). The training and demonstration stand is a mobile platform shown in Fig. 1.

![Training and demonstration stand](image)

**Figure 1.** Training and demonstration stand: 1 – tool; 2 – heated table; 3 – reusable diaphragm; 4 – control panel; 5 – binder trap; 6 – compartment with binder and vacuum equipment; 7 – storage compartment

The stand includes shaping equipment (the set includes equipment for training, but when making other products in small batches, the equipment can be changed to a suitable one), heated table (the presence of a heated table shortens the binder curing time in the case of cold curing resins and reduces the binders intended for hot curing viscosity), reusable silicone diaphragm (the diaphragm allows up to 600 moldings), stand control panel, binder traps (degassers), compartment, isolated from users, where vacuum equipment and containers with binder are located, as well as a storage compartment where auxiliary and consumables are stored (tubes, resin meshes, scissors and reinforcing fabrics) [9].

A mobile vacuum station consisting of a pump and a trap (also known as a resin degasser) was considered as a traditional infusion equipment. Many companies offer similar vacuum stations, which differ from each other in the volume of the trap and the performance of the pumps. Three solutions comparison are presented in Table 1.

| №  | Accessories / Features          | Young composite manufacturer set | Training demonstration stand | Traditional infusion equipment |
|----|--------------------------------|---------------------------------|------------------------------|--------------------------------|
| 1  | Vacuum table                   | No                              | Yes                          | No                             |
| 2  | Degasser                       | Yes                             | Yes                          | Yes                            |
| 3  | Closed containers for binder    | Yes                             | Yes                          | No                             |
| 4  | Impregnation process automation| No                              | Yes                          | Yes                            |
| 5  | Unlimited size of received parts| Yes                             | No                           | Yes                            |
| 6  | Processes visual demonstration possibility | No                              | Yes                          | No                             |
| 7  | The impregnated tooling heating possibility | Yes                             | Yes                          | No                             |
| 8  | Base cost                      | RUB 768 000                     | RUB 550 000                  | RUB 400 000                    |
| 9  | Additional equipment cost (table, heating system) | RUB 0                             | RUB 0                        | RUB 200 000                    |
| 10 | The total cost                 | RUB 768 000                     | RUB 550 000                  | RUB 600 000                    |
Despite the lower cost of the infusion set, in addition to it, it is required to purchase a table and a vacuum bag heating system (for example, an IR lamp), as a result of which the set cost will exceed the cost of the training and demonstration stand. Among the stand disadvantages, one can single out the limited size of the parts obtained, which is due to the vacuum table and a certain geometry flexible diaphragm presence. On the other hand, the vacuum table and a flexible diaphragm presence significantly reduces the labor intensity of production, as well as the auxiliary components cost. An important advantage of the training and demonstration stand is the absence of the need for commissioning, as well as quick personnel who are supposed to work with the stand training. Well, the main advantage of the training and demonstration stand is mobility, which allows you to implement advanced projects almost everywhere. At the same time, in addition to the technological aspects of the selected equipment, special attention should be paid to aspects that directly affect the competencies acquisition and development [10].

Among them are [11]:
1. High degree of clarity. The equipment must fully demonstrate the process under study.
2. Safety. The equipment use must take place without endangering the student life and health.
3. User engagement. The equipment should imply the direct participation of students in the manufacturing process.
4. Focusing. Equipment should be designed in such a way that the attention of students is focused on the process being studied.
5. Economy. The annual cost of operating the equipment should be kept to a minimum.

It is quite problematic to give a quantitative or qualitative assessment of the solutions presented on the market for these parameters and to bring everything into a comparative table, since there is no objectivity factor (except for economy), but it is still possible to conduct an analysis. All three solutions with a sufficient degree of clarity demonstrate the future composite impregnation process thanks to transparent membranes and vacuum films. The same goes for user engagement and focus. When analyzing safety, it should be noted that the use of a training and demonstration stand compares favorably with existing analogues, since students have no direct contact with the binder, which means that they do not inhale harmful fumes from epoxy or polyester resins. In addition, when using a training and demonstration stand, completely different requirements are imposed on the room where it is operated. When using traditional infusion equipment and the «Young composite manufacturer set», a specialized room with supply and exhaust ventilation is required, and a separate area where the compound is prepared (a mixture of polymer resin and hardener). When using the training and demonstration stand, the resin and hardener are poured into closed containers in advance, and the mixing of the components in predetermined proportions occurs automatically. Thus, there is no need for premises specialized preparation in terms of ventilation, which increases the using this equipment possibilities [12]. From an economic point of view, the use of a training and demonstration stand is much cheaper, because there is no need to purchase a number of auxiliary and consumables, and the reusable membrane resource allows maintenance of the stand every few years, even with intensive use.

3. Conclusions
The most important stage in the formation of competitive human resources, first of all, for the EIC is the accumulation and development of hard competencies based on knowledge, skills and abilities in advanced industries, which, of course, includes the industry of new materials. It is impossible to accomplish the enterprises digital transformation without introducing, in particular, composites, and for this there must be synergy between the companies and the customer, the link between which is the EIC. In turn, the EIC should be provided with highly qualified personnel, for which it is necessary to use ultimatum solutions that meet modern requirements both in personnel training and in the composites production in a small batch, which includes a training and demonstration stand.

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