Acta
Universitatis
Danubius

ŒCONOMICA

Composite AI – A Financial Simulation

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Abstract: Composite materials tend to increasingly replace classical materials in a wide variety of fields. The major market segments of composites are: boats, cars, heavy duty vehicles, building and constructions, sports and recreation, wind power, corrosion resist elements, aeronautics and military applications. However, there are many other very important applications and new products are released every year. There are various reasons why new materials can be favoured. Typical examples include materials which are less expensive, lighter, stronger or more durable when compared with common materials. Considering the above, but also the importance of using artificial intelligence in almost all areas of activity, the existence of software that provides numerical and graphical results on various issues in the field of composite materials can have a major financial advantage for both those who use it and for the companies that provide such services.

Keywords: artificial intelligence; machine learning; data analysis; composites; simulation and modelling

JEL Classification: G17 Financial Forecasting and Simulation

1. Introduction

Over the last fifty years, composite materials have developed the fastest. Due to a special versatility, the volume and number of fields of use of composite products have constantly increased, developing new solutions that improve the quality of products and their attractiveness for new markets. Composites are no longer the privilege of the aerospace, defense, or high value industries. They have quickly become a way to achieve high structural performance at a low cost and are found all around us.

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A composite material (also called a composition material or shortened to composite, which is the common name) is a material which is produced from two or more constituent materials. These constituent materials have notably dissimilar chemical or physical properties and are merged to create a material with properties unlike the individual elements. Within the finished structure, the individual elements remain separate and distinct, distinguishing composites from mixtures and solid solutions.

More recently researchers have also begun to actively include sensing, actuation, computation and communication into composites, which are known as robotic materials.

Composite AI (artificial intelligence) combines different AI techniques to achieve better results. Composite AI consists of new and innovative applications of artificial intelligence, machine learning and other evolving concepts of data-driven approaches in the field of developing new materials and structural systems (at nano, micro and macro scales), along with the aspects of various deterministic and stochastic analysis, optimization, inverse problems and experimental investigation. This may generate new knowledge around these materials, investigating the mechanical and other multi-functional behaviours, fine-tuning of their compositions, and exploring their potential in different applications.

The present paper is structured as follows: in the second section there are presented general things about composite materials and the advantages of using artificial intelligence and in the third section we have a case study related to a company that wants to start a business in offering consulting services in the field of composite materials, based on artificial intelligence algorithms.

2. Composite Materials and Artificial Intelligence

2.1. Classification of Composite Materials

There are several variants of defining composites. The most comprehensive, best characterizing their nature is that given by P. Mallick? According to Mallick, "a composite material is a combination of two or more chemically different materials with an interface between them. The constituent materials maintain their separate identity (at least at the macroscopic level) in the composite; however their combination generates properties and characteristics different from those of the component materials in part. One of the materials is called a matrix and is defined as forming a continuous phase. The other main element is called reinforcement and is added to the matrix to improve or modify its properties. Reinforcement is the discontinuous phase, evenly distributed over the entire volume of the matrix." Fibers are the elements that give the assembly the characteristics of resistance to stress. Compared to the matrix, the effort that can be taken over is clearly superior, while

the corresponding elongation is reduced. The matrix has a much higher elongation and breaking resilience, which ensures that the fibers break before the matrix gives way. However, it should be emphasized that the composite material is a unitary assembly, in which the two phases act together, as suggested by the stress-elongation curve for composite. Broadly defined, a composite material is a set of distinct materials, which has characteristics that the constituent materials do not have in part.

Taken as a whole, the main categories of fiber-reinforced composites are the following:

1. Polymer matrix composites - usually thermosetting resins (epoxy, polyimide or polyester) or thermoplastics, reinforced with glass, carbon, boron or aramid (Kevlar) fibers, ceramic single crystals or, more recently, metal fibers. They are mainly used in applications involving relatively low working temperatures (reaching, exceptionally, for thermoplastics manufactured by injection, at a maximum level of 400°C).
2. Metal matrix composites - most often based on aluminum, magnesium, titanium or copper alloys, in which boron, carbon (graphite) or ceramic fibers (usually alumina or silicon carbide) are introduced. The working temperature (usually not more than 800°C) of such a composite is limited by the level of the softening or melting point which characterizes the matrix material. If the intended application involves high temperatures, then the use of nickel-based alloys or super alloys is recommended as a matrix. Their disadvantage is that they have high specific weights, leading to an increase in the mass of the final structure.

3. Composites with ceramic matrix - have been developed especially for applications with very high working temperatures (above 1000°C); the most used basic materials are silicon carbide (SiC), alumina (Al2O3) and glass, and the usual reinforcing fibers are also ceramic (usually in the form of very short staple fibers).

4. "Carbon-carbon" composites - with carbon or graphite matrix and reinforcement with fibers or graphite fiber fabrics; they are very expensive, but also incomparable with other materials due to their resistance to high temperatures (up to 3000°C), coupled with the low density and low coefficient of thermal expansion. The most common fiber-reinforced composites are carbon fiber, fiberglass and Kevlar.

Other classification criteria concern the state of aggregation of the matrix and the dispersed material, the configuration geometry of the complementary material, the mode of distribution of the complementary material, the way of making the contact surface or the size of the material complementary. Given the great diversity of materials it is obvious that there are many criteria for their classification and those mentioned above were just some of them.

2.2. Methods of Fabrication of Composite Materials

Normally, the fabrication of composite includes wetting, mixing or saturating the reinforcement with the matrix. The matrix is then induced to bind together (with heat or a chemical reaction) into a rigid structure. Usually, the operation is done in an open or closed forming mould. However, the order and ways of introducing the constituents alters considerably. Composites fabrication is achieved by a wide variety of methods, including:

• advanced fibre placement (automated fibre placement) - Fibre Placement is an automated composites manufacturing process of heating and compacting synthetic resin pre-impregnated non-metallic fibres on typically complex tooling mandrels;

• fiberglass spray lay-up process - Spray-Up also known as chop method of creating fiberglass objects by spraying short strands of glass out of a pneumatic gun. This method is used often when one side of the finished product is not seen, or when large quantities of a product must be made cheaply and quickly without regards to strength. Corvette fenders and boat dinghies are commonly manufactured this way;

• filament winding - Filament winding is a fabrication technique mainly used for manufacturing open (cylinders) or closed end structures (pressure vessels or tanks). This process involves winding filaments under tension over a rotating mandrel;

• Lanxide process - The Lanxide process, also known as pressure less metal infiltration, is a way of producing metal-matrix composite materials by a process of partial reaction; the process involves a careful choice of initial alloy (usually aluminium with about 3% magnesium and about 10% silicon), and then the maintenance of conditions in which the polycrystalline reaction product has a mechanical composition such that metal is drawn up through it towards the oxidiser by capillary action, so the composite material grows downwards;

• tailored fibre placement - Tailored fibre placement (TFP) is a textile manufacturing technique based on the principle of sewing for a continuous placement of fibrous material for composite components;

• tufting - Tufting is an experimental technology that consists of inserting a thread through a layered dry fabric, using a needle that, after insertion, moves back along the same trajectory leaving a loop of the thread on the bottom of the structure. It is a technology developed for and used within the thermoset resin injection manufacturing route;

• z-pinning - Z-pinning is a technique to insert reinforcing fibres (also called Z-pins or Z-fibres) along the Z-direction of continuous fibre-reinforced plastics. Z-pins can be made of metal or precured unidirectional composite fibres. Composites are tested before and after construction to assist in predicting and preventing failures. Pre-construction testing may adopt finite element analysis (FEA) for ply-by-ply analysis

of curved surfaces and predicting wrinkling, crimping and dimpling of composites. Materials may be tested during manufacturing and after construction by various non-destructive methods including ultrasonic, thermography, X-ray radiography, and laser bond inspection for bond strength integrity in a localized area.

Typical engineered composite materials include:
• Reinforced concrete and masonry;
• Composite wood such as plywood;
• Reinforced plastics, such as fibre-reinforced polymer or fiberglass;
• Ceramic matrix composites (composite ceramic and metal matrices);
• Metal matrix composites;
• and other advanced composite materials.

2.3. Advantages of Using Artificial Intelligence

Software for composite materials generally has the following characteristics:
- allows the calculation of various indicators and necessary parameters in the fields in which the work with composite materials is done;

- allows the design of various buildings and objects made of composite materials;

- allows the simulation of the effects of various external factors on composite materials;

- allows the visualization of various cracks that may appear in composite materials under the action of one or more external factors;

- allows the determination of composite materials suitable for various activities;

- allows the discovery of new composite materials with various properties.

Such software uses both classical algorithms, specific to the field of composite materials, and artificial intelligence algorithms. Services offered by such software can be several:

• Offering the possibility to use the software, on a subscription basis, for mostly legal persons who need various results from those listed above.

• Technical consultancy service in areas using composite materials. This service can be based on payment per benefit. The service involves the use of software to obtain the necessary information and the interpretation of information obtained by an expert of the company that owns the software. Through this interpretation is possible to obtain various necessary documents in the respective fields: expertise reports on some works performed, necessary approvals for some works to be performed, design documents for works to be performed, feasibility studies, as well as any other documents that require some expertise.

• Support in the research of composite materials. This part can aim at people working in research and can give them the opportunity to use software to test hypotheses or to simulate experiments. The service also includes a part of documentation as well as a part of data interpretation, performed by an expert of the company that owns the software.

The services offered can be addressed to both legal entities and individuals. Legal entities interested in this type of services are companies that use composite materials in their activity. In particular, we identify here the companies involved in the field of construction, both in the field of building construction and in the field of machine construction, equipment construction and others. All these companies need both to carry out studies on the materials used and to obtain various expert opinions regarding the strength and safety of the materials. Interested individuals are also divided into at least three categories: people working in research who need the research support service in the field of composite materials; architects or experts in the field of construction engineering; medical staff involved in working with prostheses or other effects made of composite materials.

3. Financial Impact

The financial advantages for the beneficiaries of the services listed above are obvious.
Let's now discuss the concrete situation of a company that would like to start such a business.

3.1. Company Location and Facilities

The main activity of the company is the provision of consulting services in the field of composite materials and online software utilization services. Therefore, the location of the company's headquarters does not have a great relevance in terms of running the business. The registered office of the company will be located in a personal property. In order to carry out the activity, an office space will be rented in an affordable area, a space that will allow the operation of a team of three to ten members. This space will be chosen according to the criterion of the lowest price, but the accessibility to this space will also be taken into account. Easy access to the space will help employees to move daily to and from the office, and also help with any discussions with customers held at the company's office. It is envisaged to rent a space in an area at a reasonable distance from the city center. The location will have its own parking spaces, which will allow customers to have a comfortable experience in the relationship with the company. The existence of a supermarket with IT stores is also considered, so that the supply of IT accessories is easy.

3.2. Customer Relationship and Service Delivery

- The company runs promotional campaigns on various distribution channels both online and offline. The campaigns are designed and carried out by the employed marketing expert.

- The customer contacts the company with a request for quotation through one of the communication channels provided (phone, e-mail, social networks, etc.).

- There is a prior conversation with the client to set up an appointment. If the client does not want a physical meeting, a virtual meeting is set up. During the meeting, it is evaluated exactly what the client's need is, an evaluation made by the company's experts.

- The customer is given a cost estimate, if applicable (where the subscription service is not chosen), or the most appropriate type of service for his situation is communicated to him.

- If necessary, various components are installed on the server.

- If the client wants to use the software alone, a series of training sessions take place.

- If the requested service requires human involvement from the company's experts, they carry out the activities specific to the requested service.
- In the case of subscription-based services, the software records data and runs orders given by the customer, or by company experts.

3.3. Maintenance

- The company's experts check the proper functioning of all equipment and all programs.

- If a customer has a problem, he enters a request for help in the special software intended for this functionality. Within 2 to 24 hours, one of the company's experts will check the problem and provide a solution to the customer.

3.4. Human Resources Management

To start the business, the company needs three programmers and a marketing expert. For their recruitment, the services of a specialized company will be used. They will be able to be employed either with physical work at the company's headquarters or with remote work. In addition to the strategies offered by the recruitment company, the opportunity of the existence of a possible university center within the city where it operates will also be used. A collaborative relationship will be developed with this center in order to support education but also the recruitment of students. Dedicated

social networks will also be used in the recruitment process. Recruitment announcements will also be published on the company's website. From the fifth and ninth months, the company will need two IT experts that it will recruit from the first months, using the process described above. The services of the recruitment company will be used later, until the moment when it will be profitable to set up a human resources department.

Taking into account those described above, initially, the company's activity will be based on:

- three programmers, whose main tasks will be documenting the needs and developing the software that corresponds to those needs;

- two IT experts, employed from the fifth and ninth months, respectively, who will be responsible for the maintenance of the equipment and the software related to running the business;

- a marketing and sales expert, responsible for the promotion strategy and customer relationship;

- a CEO, who will initially be in charge of most of the functions of the management system.

A large part of the services needed to carry out the activity will be outsourced in the initial development phase. For example, the financial-accounting service will be provided by a specialized company, as well as the recruitment and human resources management service. Following profitability calculations, some services may remain outsourced (e.g. accounting).

3.5. Investment Budget

Fees for setting up a company: 1,000 Ron.

• Salary expenses:

The company will have 6 employees, with 3 different functions, paid differently. Employees will also appear on the team as needed. Given the calendar of activities, there will be the following employees:

- 3 software development experts, remunerated with 12,000 Ron net per month, which means an expense of 20,400 Ron per month for the company. They will be hired from the first moment, because they will contribute to the development of the software that underlies the services offered;

- 1 marketing and sales expert, remunerated with 3,000 Ron net per month, which means 5,100 gross per month, for the company. He will be hired from the outset, as he will contribute to the promotion and sale of two of the services offered;

- 1 IT Expert, employed since the fifth month of activity, remunerated with 2,000 Ron net per month, which means 3,400 Ron per month, for the company;

- 1 IT Expert, employed since the ninth month of activity, remunerated with 2,000 Ron net per month, which means 3,400 Ron gross per month, for the company.

Total: 346,800 Ron.

• Expenses for specialized services:

- accounting: 12 months * 300 Ron / month = 3,600 Ron;
- OSH services and labor protection: 1 month * 300 Ron / month = 300 Ron.

Total: 3,900 Ron.

• Expenditure on the acquisition of tangible fixed assets, inventory items, raw materials and consumables, other investment expenditure necessary for the operation of enterprises:

- Furniture:

7 pieces computer desk * 800 unit price Ron = 5,600 Ron;
7 pieces ergonomic chair * 500 unit price Ron = 3,500 Ron;
1 piece of sofa * 800 unit price Ron = 800 Ron;
1 piece adjustable table * 800 unit price Ron = 800 Ron;

Total: 10,700 Ron.

- Licenses:

4 pieces Windows license * 500 unit price Ron = 2000 Ron;
Total: 2,000 Ron.

- Equipment:

1 piece of laptop * 3,000 Ron = 3,000 Ron;
4 pieces of computer * 3,500 unit price Ron = 14,000 Ron;

Total: 17,000 Ron.

• Inventory items:

- 1 piece inkjet printer * 400 Ron = 400 Ron;
- 2 pieces of current source with stabilization * 400 unit price Ron = 800 Ron;

Total: 1200 Ron.

• Consumables:

- 12 pieces Stationery (xerox paper, pens, diaries, organizers, toners, etc.) * 200 Ron per piece = 2,400 Ron;

- 12 pieces Household products (disinfectants, protective masks, gloves, etc.) * 100 Ron per piece = 1,200 Ron;

Total: 3,600 Ron.

• Expenditure on renting premises (including warehouses), spaces for carrying out various activities of the enterprise, equipment, vehicles, various goods:

- Rental of storage space: 12 months * 3,000 Ron / month = 36,000 Ron;
- VPS server rental: 2 pieces * 1 year * 1,000 Ron / year = 2,000 Ron;

Total: 38,000 Ron.

• Utilities related to the operation of enterprises:

- electricity: 12 months * 300 Ron / month = 3600 Ron;
- water / sewerage: 12 months * 100 Ron / month = 1,200 Ron;
- thermal energy: 12 months * 150 Ron / month = 1800 Ron;
- garbage collection: 12 months * 150 Ron / month = 1800 Ron;
- cleaning service: 12 months * 300 Ron / month = 3600 Ron;

Total: 12000 Ron.

• Financial and legal (notarial) expenses related to the operation of enterprises:

- Notary (and legal) expenses: 12 months * 100 Ron / month = 1,200 Ron;

Total: 1,200 Ron.

• Connection to computer networks related to the operation of enterprises:

- telephony / fixed internet subscription connection service: 12 months * 65 Ron / month = 780 Ron;
- mobile phone / internet subscription connection service: 12 months * 100 Ron / month = 1,200 Ron;

Total: 1,980 Ron.

• Information and publicity expenditure related to the operation of enterprises:

- 500 pieces of business cards * 1 Ron / piece = 500 Ron;
- web promotion services: 12 months * 3,000 Ron / month = 36,000 Ron;

Total: 36,500 Ron.

Total investment expenses: 475,880 Ron.

3.6. Income Forecast

According to the business plan, the activity is expected to start with the first month of activity, for some services and with the fifth month for other services. Following the advertising carried out according to the marketing plan, it is expected to reach the level of 32 subscriptions for the use of the software for the behavior of composite materials. At the same time, it is expected to have between 6 and 12 services per month for the consulting service in the field of composite materials. Regarding the research support service, there are expected between 2 and 4 benefits per month.

Services involving the work of experts have set an hourly rate and average number hours per benefit in order to obtain the rate per benefit.

The software use service is based on a fixed cost subscription. The cost of this service is 1,000 Ron per month, the equivalent of 200 euro. The consulting service in the field of composite materials has an estimated tariff of 200 Ron per hour (equivalent to 40 euro) and was estimated at a minimum of 10 hours per service. These hours include taking data from the customer, entering data into the software where appropriate and making consulting reports. The tariff is a minimum; it can vary depending on the characteristics of the project.

The research support service has an hourly rate of 100 Ron and a minimum number of 30 associated hours, for an estimated rate of 3,000 Ron per service. During these hours are included the taking over of the data from the client, the documentation on the proposed project, the realization of the necessary models with the help of the software and the writing of the research reports.

The total estimated income for the first year: 522,000 Ron.

Thus, if we look at the forecasts of expenses and income, we can conclude that for a first year since the establishment of the company there is a profit of 47,000 Ron, the equivalent of 9,400 euro.

4. Conclusions

Composite materials are part of the "new materials" category and are specially designed to meet special requirements. However, the mechanical characterization of composite materials is difficult due to the multitude of parameters that must be taken into account in order to express the material's response to the different stress conditions. The recent advancements in artificial intelligence and machine learning have further accelerated the progress in developing new composites and metamaterials across different length-scales. Thanks to AI, through the use of ever-increasing databases, the number of tests on compounds can be virtually multiplied in a much shorter time and, obviously, with much lower costs than physical tests performed in the laboratory. Furthermore, as shown above, the financial advantage

can be huge for both the beneficiary and the provider of services using AI technology and technics.

5. Acknowledgement

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