



Market Opportunity of Some Aluminium Silicon Alloys Materials through Changing the Casting Process

George CHIRITA*, Mioara CHIRITA**, Delfim SOARES***, Filipe Samuel SILVA****

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ABSTRACT

Fatigue is considered to be the most common mechanism by which engineering components fail, and it accounts for at least 90% of all service failures attributed to mechanical causes. Mechanical properties (tensile strength, tensile strain, Young modulus, etc) as well as fatigue properties (fatigue life) are very dependent on casting method. The most direct effects of casting techniques are on the metallurgical microstructure that bounds the mechanical properties. One of the important variables affected by the casting technique is the cooling rate which is well known to strongly restrict the microstructure. In the present research has been done a comparison of fatigue properties of two aluminum silicon alloys obtained by two casting techniques. It was observed that the fatigue life is increasing with 24% for Al12Si and 31% for Al18Si by using centrifugal casting process instead of gravity casting. This increasing in fatigue life means that a component tailored from materials obtained by centrifugal casting will stay longer in service. It was made an estimation of the time required to recover the costs of technology in order to use the centrifuge process that will allow to obtain materials with improved properties. The amortization can be achieved by using two different marketing techniques: through the release of the product at the old price and with much longer life of the component which means "same price - longer life", or increasing price, by highlighting new product performance which means "higher price - higher properties".

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1. Introduction

In materials science, **fatigue** is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The nominal maximum stress values are less than the ultimate tensile stress limit, and may be below the yield stress limit of the material.

One of the most common mechanisms by which engineering components fail is considered to be the fatigue which is responsible for at least 90% of all service failures attributed to mechanical causes. Failure occurring under conditions of dynamic loading is called fatigue failure, and is particularly insidious because it occurs without any obvious warning, resulting in sudden or catastrophic failure [1]. Fatigue can also be defined as "the process of progressive localized permanent structural change occurring in a material subjected to conditions that produce fluctuating stresses and strains at some point or points and that may culminate in cracks or complete fracture after a sufficient number of fluctuations" [2]. Three basic factors are necessary to cause fatigue failure: maximum tensile stress of sufficiently high value, a large variation or fluctuation in the applied stress, and a sufficiently large number of cycles of the applied stress [1]. The fatigue fracture surface generally consists of three main regions that correspond to fatigue crack initiation, fatigue crack growth, and fast fracture [3, 4, 5, 6].

To reduce the time-to-market of a product, it is beneficial to have in the design phase, access to fatigue information that could bring improvements of product reliability and consumer confidence as well as the elimination of costly recalls and premature product failures.

For example, fatigue analysis early in the design phase can locate areas that are likely to succumb to fatigue quickly, minimizing expensive and unnecessary prototypes and tests.

Predicting fatigue life is a critical aspect of the design cycle because virtually every product manufactured will wear out or break down. The critical issues are whether the product/component/assembly will reach its expected life, and if damaged, whether the product/component/assembly will remain safe in service until the damage can be discovered and repaired. And as with most simulation analysis, the earlier fatigue analysis is deployed in the product development process, the more benefits will be realized, including safety and economic use.

* Faculty of Mechanical, Dunarea de Jos University of Galati, Romania; **Faculty of Economics and Business Administration, Dunarea de Jos University Galati, Romania; ***, ****School of Engineering, University of Minho, Guimaraes, Portugal. E-mail addresses: georgechirita@gmail.com (G. Chirita); mioarachirita@gmail.com (M. Chirita)

Previous research reported in literature on Al-Si casting alloys has demonstrated that porosity is detrimental to fatigue life as cracks initiate freely at pores. Casting defects have a detrimental effect on fatigue life by shortening not only fatigue crack propagation but also the initiation period. The decrease in fatigue life is directly correlated to the increase of defect size. There exists a critical defect size for fatigue crack initiation, below which fatigue crack initiates from other competing initiators such as eutectic particles and slip bands. Castings with defects show at least an order of magnitude lower fatigue life compared to defect-free materials. Porosity is more detrimental to fatigue life than oxide films.

However, with improved casting techniques, porosity can be greatly reduced and other microstructural features influence fatigue life. In particular, Si particles have been shown to play an important role in the initiation and subsequent propagation of fatigue cracks. Pores, Si particles and intermetallic phases were shown to cause fatigue crack initiation. So, if a product tailored from a material with less porosity and less other factors that are responsible of shortening life period will stay longer in service, it is assumed that the manufacturers will try to recover the investment. Recovering the investment in research to bring on the market a new product with higher properties means in almost all cases to increase the final price of the product.

Pricing is the process of determining what a company will receive in exchange for its products. Pricing factors are manufacturing cost, market place, competition, market condition, and quality of product. Pricing is also a key variable in microeconomic price allocation theory. Pricing is a fundamental aspect of financial modelling and is one of the four P's of the marketing mix. The other three aspects are product, promotion, and place. Price is the only revenue generating element amongst the four P's, the rest being cost centres. [7]

Pricing is the manual or automatic process of applying prices to purchase and sales orders, based on factors such as: a fixed amount, quantity break, promotion or sales campaign, specific vendor quote, price prevailing on entry, shipment or invoice date, combination of multiple orders or lines, and many others. Automated systems require more setup and maintenance but may prevent pricing errors. The needs of the consumer can be converted into demand only if the consumer has the willingness and capacity to buy the product. Thus pricing is very important in marketing.

Some authors argue that the recipe for success in the future is to combine the creative mix design components: performance, quality, durability, esthetics and cost. Each element depends on others and vice versa, so well that it is impossible to define them separately, in financial terms and in terms of competitiveness. [8]

Innovation is generally regarded as the main engine of economic growth in today's global economy. By introducing innovations in practice to obtain products with improved quality characteristics, quality services, new more efficient production processes, etc. There are many reasons for manufacturers to innovate, including: market share, the conquest of new markets, improve product quality, expand the range of products, replacing obsolete products, reducing environmental impact, etc. Innovation is inextricably linked to creativity. Innovation process involves the following major steps:

Figure 1. Innovation process



Source: adapted by [9]

This phases depending on the indicators such the technology which should be implement, the size of the implementation team, the company's budget, the results of discussing with the experts, in order to explore new solutions and applying innovation methods.

In the conditions in which was launched a new product on the market, different from all competitive products, with innovative character, it is necessary to invest significant resources in the first phase of market evolution, to attract innovators and buyers.

Success of the new product will depend on the extent to which benefits and product image provided by the supplier will get the first two categories of customers: assume the risk of buying the product; and the desire to be the first to experience something new.

Considering that on the market has been launched a new product, this action is closely linked to the technical innovation. During the launch, sales are low, consumers are skeptic, in testing now the new product, and in general the total costs are high. If the product has a high degree of novelty, in this phase there are few or no competitors, sales prices can be high because of low demand elasticity with respect to product price.

Launching a new product on the market can be made "whispered" or "resounding". The first option involves placing the product on a narrow or an extended market segment, without any promotion campaign in the hope that the information is transmitted from one consumer to another, in words, fact that it will be favorable and will support the new product. The second option represents the case of the big companies which often use joint product launch campaigns, making extensive advertising campaign coordinated, promotional activities, intensive distribution and, sometimes, may be used exclusive distribution.

Enterprises can apply different types of innovative strategies, such as: [10]

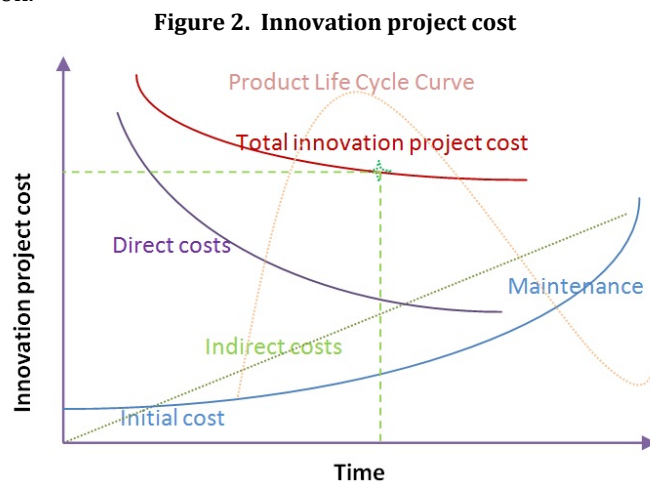
- Offensive strategy that seeking technological and market supremacy, the continuous improvement and introduction of new products;
- Dependent strategy that can be developed for satellite companies, often sub-contractors;
- Opportunistic strategy, is seeking new market opportunities, without relying on research and development or a complex design, but on finding market segments.

As regarding the specialty products, the manufacturer can choose a target market, or qualified audience, which refers to the sector most likely to want, or need a company's products or services.

Some products have an immediate success on the market, while others need more time to gain acceptance by customers. Attracting potential customers should be a priority for the organization, especially in conditions where resources were invested in the development of product improvements.

In order to obtain a rapid market advantage, the launch of new product has to be done at a high price and a sustained promotional effort. In those cases when the product market is very little known, even at high prices (due to its performance), the company faces a potential competition, so the companies wants to create preference for its brand among consumers. [11]

Slow market penetration strategy involves the launch of the product to achieve a low cost and with less expense of promotion. This strategy is used in cases when the product is relatively well known, and the product market is large; the consumers are price sensitive and the potential competition is limited. In case that the product is the result of innovations, most commonly used are realizing the advantage of market price, or price market penetration.



The length of time required to recover the cost of innovation. The payback period of a given investment or project is calculated as: [12]

$$P = CP / ACI$$

where:

P - Payback period of a given investment

CP - Cost of Project

ACI - Annual Cash Inflows

The payback period of a given investment or project is an important determinant of whether to undertake the position or project, as longer payback periods are typically not desirable for investment positions.

2. Experimental methods

The materials used for experiments were selected from two commercial Al-Si alloys (table 1). The alloys chemical composition is presented in table 1.

Table 1. Chemical composition of the alloys as obtained by (SEM/EDS)

	Si	Fe	Co	Mg	Ni	Mn	Zn	Ti	Sb
Alloy B	12,09	0,27	0,58	1,34	1,26	0,09	0,04	0,06	0,05
Alloy C	18,89	0,90	0,52	1,20	1,37	0,12	0,24	0,04	0,11

The materials were melted in an induction vacuum furnace at a temperature of about 100°C above their *liquidus* temperature and then poured into a steel permanent mould. Two casting processes were used – vertical centrifugal casting and gravity casting. The permanent mould was preheated at 130 °C for all castings. On vertical centrifugal castings the mould was rotated around the central axis of the casting machine at 450 rot/min and the molten aluminium was poured into the mould cavity by centrifugal force. For gravity castings, the same induction vacuum melting equipment was used and the same melting temperatures as on centrifugal casting were used. However, in this case, the melt was manually poured into the mould.

At least five ingots for each casting technique were produced. Two specimens from each ingot, from the centrifugal castings and from the gravity castings were cut in order to compare the fatigue properties of the aluminium alloy. Globally, more than 30 specimens were tested, 15 for each casting.

Fatigue tests were carried out on a well known rotating bending fatigue machine testing machine at room temperature. Samples were analysed by optical and Scanning Electron Microscopy/Energy Dispersion Spectroscopy (SEM/EDS) in 3 different zones and chemical compositions were made in area mode for 120 seconds. Metallurgical features were quantified by image analysis.

Figure 3. Position from where fatigue test specimens were taken: a) gravity ingots (GC and VGC), b) centrifugal ingots (CC)

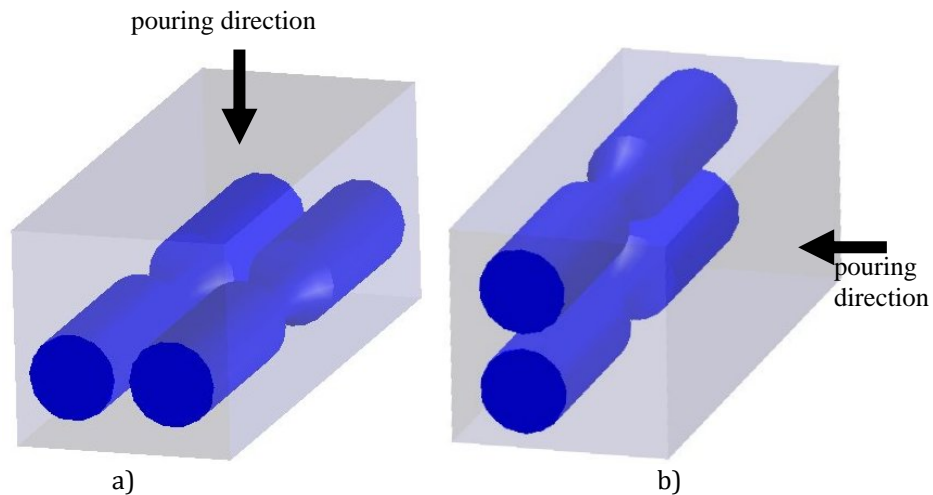
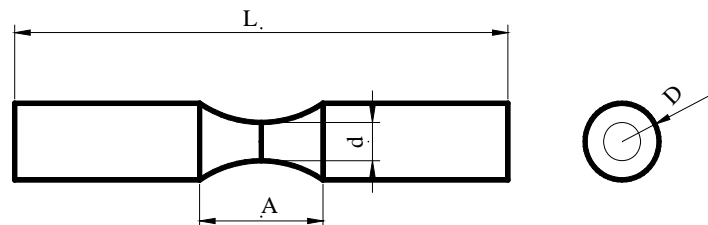


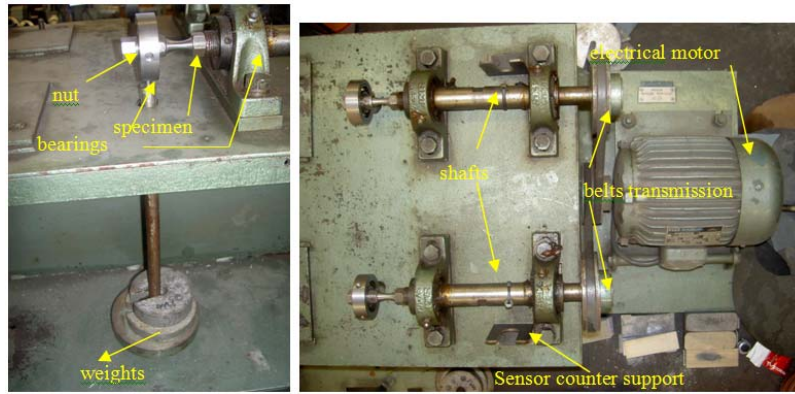
Figure 4. Rotating bending fatigue specimen dimensions



L — Over-all length	80 mm
A — Length of reduced section	20 mm
d — Diameter of minimum reduced section	6 mm
D — Diameter of specimen	12 mm

The fatigue tests were performed on rotating beam fatigue machine from Material Testing Laboratory – Minho University (Figure 5). All the components of the equipment are described in figure 5. The tests were done on two specimens on the same time operated by two different belts transmissions coupled together on the electrical motor.

Figure 5. Rotating bending fatigue machine (Material Testing Laboratory – Minho University)



3. Results and discussion

Microstructural, manufacturing, and environmental factors can cause high local stresses and therefore act as fatigue initiation sites. Typical microstructural factors in Al-Si alloys include brittle phases, for example primary Si particles, pores and oxides. Si particles have been shown to crack and decohere at the particle/matrix interface under cyclic loading and so act as initiation sites. Pores and other inclusions also act as stress raisers that's why they are considered the most common reducer of fatigue life of the casting process. The centrifugal process reduces the volume fraction of pores and brings some micro structurally improvements like volume fraction of eutectic and Silicon lamellas. In figures 6 to 7, it is shown the S-N (Stress vs Number of cycles) curves for the gravity and centrifugal castings of the two alloys studied. The fatigue properties improvements of the two aluminium silicon alloys studied in this research are obtained by the presence of several forces applied to the melt during the pouring and solidification due to a combination of the dynamics of fluid (melt), the vibration and centrifugal pressure. This can be explained by the fact that, the fluid dynamics due to the inherently vibration of the equipment and respectively due to the centrifugal pressure make the melt during solidification initiate more nuclei of solidification. Then, the centrifugal pressure concentrates the nuclei of solidification to the furthest point of the mould (where the pressure is higher) fact that explains the obtained results which are higher on one side of the ingots which corresponds with the side of the mould where the pressure is higher and smaller on the other side where the pressure is smaller. The rotating bending fatigue specimens obtained by centrifugal casting seem to resist longer than those obtained by gravity casting at same stress level applied. The fatigue limit on centrifugal casting of alloy A (Figure 6) has increased with 24.5% compared to gravity casting and for alloy B the difference between castings techniques is even bigger showing an increase by 31% compared to gravity casting (Figure 7).

Figure 6. S-N curves for centrifugal and gravity castings of alloy A

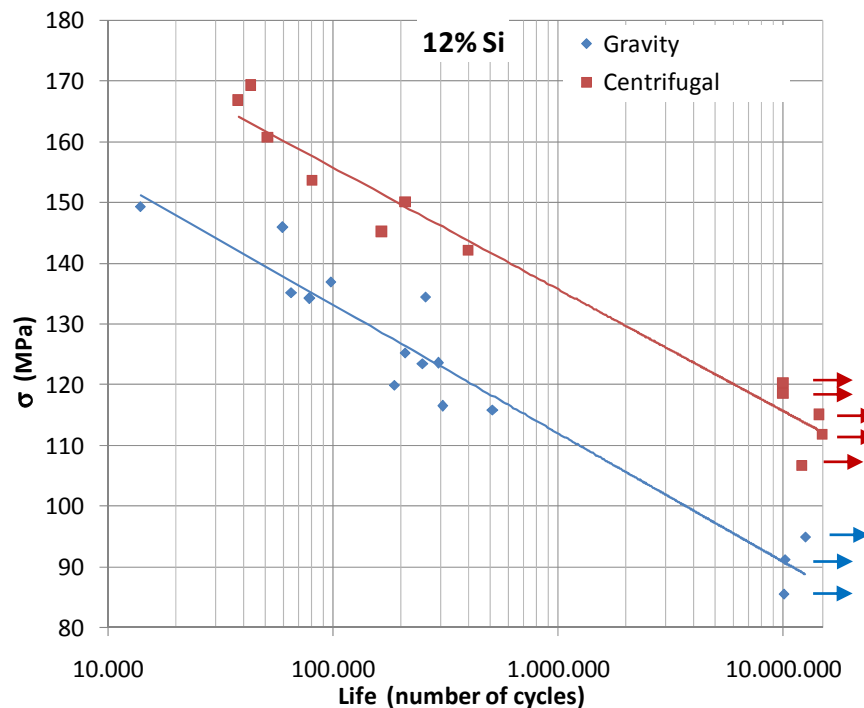
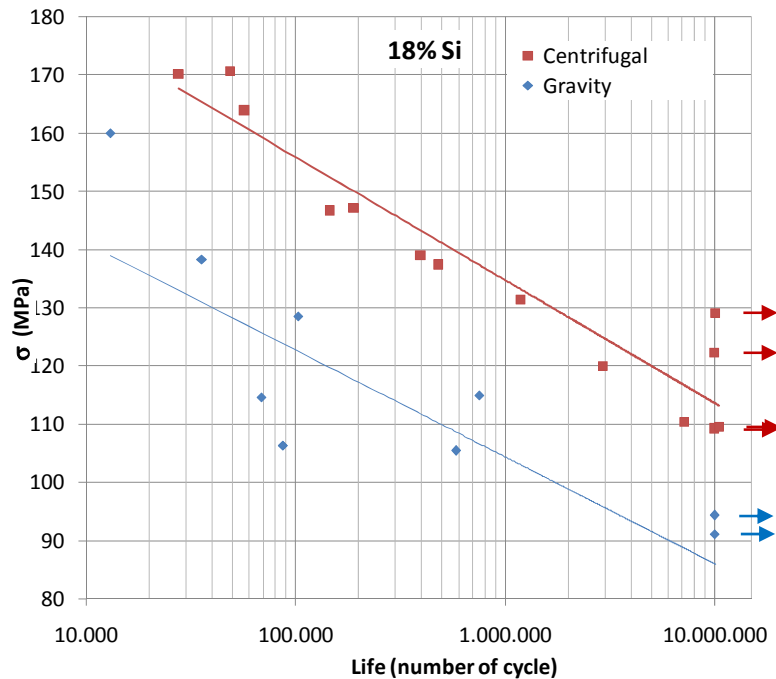


Figure 7. S-N curves for centrifugal and gravity castings of alloy B, σ - stress amplitude



4. Conclusions

By changing the casting process could be obtained an improvement of fatigue life of about 25% for Al12Si and 30% for Al18Si.

Based on the fatigue results of both materials studied, a final product made from any of these materials obtained by centrifugal casting will stay in service longer by about 25%. Taking into consideration that these two materials studied are used for example in automotive industry to obtain engine pistons, it can be concluded that the costs for maintenance will decrease by delaying the periods of inspections.

Because this technology does not mean bringing a new product on the market but is improving the properties of the existing product, the best approaching on marketing strategy could involve higher properties and the same price. This could be done by marketing campaign oriented on emphasizing the better properties of the product obtained by centrifugal technology keeping the same price. This strategy is fitting better for large companies because they are recovering the research investment not only by the product itself but through other products of the same brand.

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