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Biomechanical Analysis of Fatigue Behavior of a Fully Composite-based Designed Hip Resurfacing Prosthesis

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Abstract

The Hip resurfacing prosthesis is subjected to different stresses resulting from the different positions of the human walk, thereby generating dynamic stresses that vary with time, leading the implant material to fatigue failure. It is important to study the fatigue behavior of the prosthesis material and to ensure its long lifetime. We proposed a new composite material named CF/PA12 composed of carbon fibers with a polyamide 12 resin, whose biocompatibility had been demonstrated in laboratories. In this study, we investigated the static and dynamic behavior at different Gait cycle positions of a Hip resurfacing prosthesis entirely made of new CF/PA12 composite. A fatigue behavior will be deducted by a Finite Element Analysis using the commercial SolidWorks software compatible with the Abaqus finite element code. Static and dynamic analysis were conducted considering normal walking and climbing stairs loading at different Gait cycle percentages of 2, 13, 19, 50 and 63%. The results obtained showed that Hip resurfacing prosthesis fully made of new CF/PA12 composite was very far from fatigue and therefore from failure.

Keywords: Hip resurfacing prosthesis, fatigue behavior, CF/PA12 composite, FEA

1. Introduction

The Hip resurfacing prosthesis is an alternative to the total Hip prosthesis, usually implanted in active and dynamic young patients. The forces applied to the Hip implant due to human activities generate dynamic stresses that vary over time and cause material fatigue and rupture of the implant, so the evaluation of the lifetime of biomaterials and structures in service is essential. The two main implant elements are the head and the cup, which ensure functionality of the joint. Many studies have been carried out in order to study the biomechanics of various activities constituting the daily life of patients to quantify the forces acting at the joints. It has been demonstrated that the joints undergo shocks at each contact of the heel with the sol, generating a force that can be up to one and a half times than the forces usually measured (Hausselle 2007). It has been demonstrated that the head and the acetabulum of a Hip prosthesis were subjected to fatigue compression (Hamza 2002). A Large research exists in the literature on fatigue and rupture behavior on total Hip arthroplasty with various materials. Mechanical properties of a composite material proposed by J.U.Perez (2012) named ZTA (zirconia toughened alumina), combined with excellent biocompatibility, resistance to wear and shock and more resistance to stresses before it presents a crack, make this material the best option for total Hip prosthesis. In this field, nacre can be reliably compared with existing medical bioceramics (Al2O3 and ZrO2), with the aim of producing implant biomaterials with favorable compression fatigue behavior (Hamza 2016).

For hip resurfacing prosthesis frictional couple, mechanical behavior is the most treated, ceramic on ceramic couple is proposed to avoid the potential problem caused by metal ions generated by current cobalt-chromium prosthesis. Using metallic femoral and acetabular prostheses with alumina coatings instead of whole alumina prostheses was found to significantly reduce the predicted contact pressure distribution (Ahmet C. Cilingir 2010). The study of Bidyut Pal and al. (2010) showed that the use of stiffer ceramic components elevates stresses and strain coupled with increased stress/strain shielding in the resurfaced femur.

On the other hand, the fatigue and rupture behavior of a Hip resurfacing friction couple are rarely studied. G.S. Matharu (2015) observed as clinical outcomes, high rates of early failure of five hip resurfacing with a new composite ceramic (two-thirds polyurethane and one-third ceramic alumina) used for the acetabular component. Wen Zhang and al. (2010) investigated hip resurfacing lifetime predictions under static load, silicon nitride compared to alumina as ceramic materials, is indeed mechanically reliable and ideal for Hip resurfacing implant. This significant number of researches on the application of ceramics in Hip prosthesis whether total or resurfacing, unfortunately have not resulted in a definitive solution to avoid the risk of its fragility, so a proposal of another material is essential.

Many authors proposed the use of a composite material, P.Subhedar (2016) suggested the CF/PA12 composite as a more suitable material for Hip implant than metals and ceramics.

In this regard, this article aims to study the resistance of the Hip resurfacing prosthesis to applied dynamic loads and fatigue risk, using this new composite named CF/PA12, on a carbon fiber-based polymer (carbon fibers/polyamide12), whose biocompatibility had been demonstrated in the laboratory (S. Dimitrievska 2007; Dimitrievska et al. 2008). It presents a superior bioactivity in vitro and in vivo response to the hydroxyapatite coated composite femoral components (S.A. Hacking and al., 2010). Mechanical testing of femoral stems made from a carbon-fiber reinforced polymer composite were discussed in detail through M. Campbell, Bureau and Yahia (2008) study, the conclusion of this work shows that the bone-matching properties of this composite total hip prosthesis and its excellent fatigue resistance far exceeding the required fatigue resistance make CF / PA12 candidate material of choice for orthopedic appliances such as total hip prostheses. In addition, the application of a hip resurfacing cup made of carbon fiber/polyamide 12 CF/PA12 composite covered with a thin layer of cobalt chrome had the potential to reduce stress shielding, preserve bone stock and prevent from bone fracture compared to conventional metallic Hip resurfacing implants (Bougherara and Bureau, 2008). Vadean and Yahia (2007) proposed a comparison between Hip stems made of titanium alloy and CF/PA12 composite, stresses in composite stem are lower than those in Titan stem, and that the femoral bone implanted with composite structure sustains more load than the one implanted with Titane stem. Bougherara, Bureau and Yahia (2009) concluded from their study that CF/PA12 composite stem generates a better bone density pattern compared with the Titane based stem, indicating the effectiveness of the composite stem to reduce bone resorption caused by stress-shielding phenomenon, this may result in an extended lifetime of total Hip arthroplasty. CF/PA12 composite stem might offer a better compromise between stress shielding and micromotions than the Titan stem with the same external geometry, these results obtained by Caouette, Yahia and

Bureau (2011). Moreover, Bougheraraa and al. (2011) compared using finite element analysis. The mechanical behavior of the composite material of the total Hip arthroplasty stem with two standard commercially available metal hip implants. The study revealed that the Composite was less mechanically stiff, compared to the standard metallic hip stems. In another investigation, a new mechano-biochemical model, which is more comprehensive in the sense that it involves the coupling effect between the mechanical loading and bone biochemistry, was used to predict long-term bone density distribution around a CF/PA12 total Hip arthroplasty stem. The results were then compared to those obtained in femurs implanted with titanium alloy Titane and cobalt–chrome–molybdenum implants. It was concluded that composite hip implant is more advantageous than metallic implant as it induces less stress shielding, develops a moderately dense trabecula at the vicinity of the implant and provides more uniform bone density (Pouria Tavakkoli Avval and al., 2011). We end with a research work on composite materials, which numerically evaluated an alternative method to cementing the stem to increase the stability of the femoral components of resurfacing implants, using the CF/PA12 composite material in the manufacture of an osseointegrated stem. This new implant with composite stem has therefore reduced the deviation of stresses compared to current metal implants (Caouette, 2012).

This research allows us to come back to certain points:

Cobalt chromium Hip resurfacing prostheses have been commercialized to date, and there are many improvements such as coatings, alloy diversity and design, but the potential problem of metal ions that is dangerous to human health remains always a disadvantage not to neglect.

The ceramic prosthesis is an interesting alternative to the metallic prosthesis and its resistance to corrosion and wear attracts attention, the disadvantage is that Ceramics fragility leads to an arthroplasty revision. We concluded that a long lifetime of a ceramic prosthesis is not at all obvious.

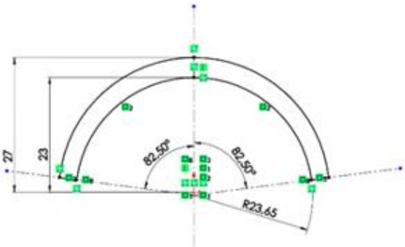
This new composite material (CF/PA12) has proven its biocompatibility in laboratories, its imitation to the human bone function that will allow a good prosthesis fixation, and its resistance to fatigue, all these positive characteristics led us to realize our study which is a static, dynamic and fatigue behavior finite element analysis of the hip resurfacing prosthesis designed entirely with this new composite material. The aim of this work is to confirm a long lifetime of the hip resurfacing prosthesis fully in CF / PA12.

2. Materials and methods

2.1 Hip resurfacing model

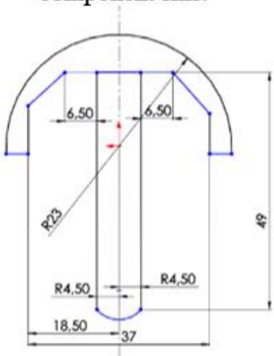
The proposed prosthesis is a Durom Hip resurfacing implant; with acetabular sizes which are 46 to 68 mm and femoral head sizes are 38 to 60 mm. Our choice was the one with 46 mm of diameter; the acetabular implant was a cup with 54 of outside diameter, both of them distributed by the company Zimmer® (2012). We have chosen a relatively large diameter because the large diameter of the head approximates the anatomy and limits the risk of dislocation. The initial offset of the Hip prosthetic is preserved as well as the length of the neck, leaving the muscles with their initial tension. The bone capital is not only preserved by preserving the center of the head and the neck, but also by avoiding unnecessary alteration of the metaphyseal-diaphysis zone of the upper end of the femur (Kluess 2008). The length of the stem (L) is L= D+3mm, D= diameter of the head, in our case equal to 46 mm, therefore L equal to 49mm, (Zhang 2010).

The femoral neck diameter is 37 mm and that of the stem is 9 mm (Kluess 2008). The Durom cup was not completely hemispherical, it was a truncated hemisphere whose angle of opening was 165°, which allowed to increase the articular amplitudes and to respect as much as possible the acetabular bone stock; also the radial clearance must be superior or equal to 120 µm (P.E. Ridon, 2016). The reduction of the radial clearance has a significant influence on the distribution of the contact pressure between the implant components (Bougherara 2008). Based on these outcomes, our diametral clearance prosthesis chosen was 130 µm. This clearance has one of the most influential characteristics of friction couples, which is defined as the difference between the internal diameter of the cup and the diameter of the head 2(R2-R1), which plays a major role in lubrication (Smith and Nephew 2011), all these dimensions are illustrated on our prosthesis model (Figure 1).



(a) Tow dimensional acetabular component skis.

(b) Three dimensional acetabular component model.



(c) Tow dimensional femoral head component skis.

(d) Three-dimensional femoral head component model.

(e) Three-dimensional assembled prosthesis model.

(f) Section illustrates the contact of prosthesis model.

Fig. 1. Geometry and model of CF/PA12 composite Hip resurfacing prothesis components.

The material used for the proposed hip resurfacing prosthesis design is CF/PA12 composite (carbon fiber composite with a polyamide 12 resin). With the increase in the number of layers of the laminate, the material is considered transverse isotropic (Caouette 2012), with six plies oriented at ($\pm 45^\circ$) represented with $[(\pm 45^\circ)]_6$. Ply thickness considered is 0.5mm (Bougheraraa and al. 2007) (Figure 2).

All mechanical composite proprieties are summarized in Table 1.

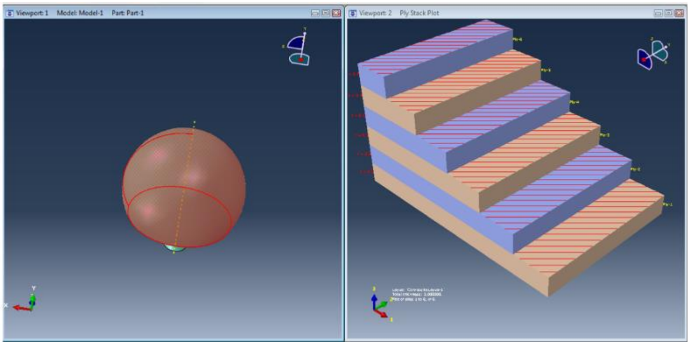


Fig. 2. Ply configurations used for CF/PA12 composite material $[(\pm 45^\circ)]_6$

properties	values
$E_1^{compression}$, $E_2^{compression}$ $E_2^{compression}$	10 [GPa]
ν_{12}, ν_{21} ν_{12}, ν_{21}	0.4
G_{12}, G_{21}	4 [GPa]
E_3	15.7[GPa]
$\nu_{13}\nu_{23}$ ν_{13}, ν_{23}	0.4
G_{13}, G_{23}	6 [GPa]
Density (P.T. Avval. 2011)	1.443[g/cm^3]

Table 1. Mechanical composite proprieties (Caouette 2012).

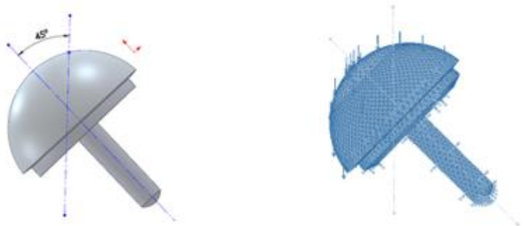
2.2 Loading conditions

In this study, a load was applied to the surface of the bearing of the implant, the concept of "Pauwels balance" shows that the hip joint supports about 3 times the weight of the body. Therefore, for a person weighing 75 kg, the force at the hip joint level can reach 2250N. In order to approach the reality, we consider a normal walking daily activity for our static analysis. Force components acting on the femoral head model allow us to reproduce all the phases of each movement by varying the Gait phase at different Gait cycle percentages of 2, 13, 19, 50 and 63% (J.P. Hunga and al., 2004). In fatigue analysis, we are interested in the maximum values forces, 13% and 50% of the gait cycle are the positions when the hip contact forces are highest because it is an unipodal support (contact of only one foot on the floor) in the gait cycle, so 2%, 19% and 63% positions, hip contact forces are minimal because of the bipodal support (contact both feet on the floor) in the gait cycle (Bonnefoy-Mazure et al. 2015). Force components values corresponding to different positions of the Gait cycle are listed in (Table 2). These force components with respect to a vertical loading, were assumed to be positioned anatomically at an inclination angle of 45° and an ante version of 0° in the pelvic and femoral bone (Ahmet C. Cilingir 2010), (Figure 3.a). Boundary conditions are applied by fixing the femoral stem component, since it is perfectly related to the surrounding bone.

Modern software using the finite element method to solve contact problems usually approaches such problems via two basic theories that, although different in their approaches, lead to the desired solutions. One of the theories is known as the penalty function method, and the other as the Lagrange multipliers method. The main difference between them is the way they include in their formulation the potential energy of contacting surfaces.

The penalty function method, due to its economy, has received a wider acceptance. The method is very useful when solving frictional contact problems, while the Lagrange method, based on multipliers, is known for its accuracy. In our case we chose a penalty function method.

The contact at the bearing surfaces is considered with friction, using a friction coefficient of 0.25 (Griza and al. 2013), this composite material resists to wear, so it is not necessary to use a high friction coefficient, to be able to resist to wear, and allow a well lubricated condition (Figure 3.b).



(a) Inclination angle of 45° of the model. (b) Loading and boundary conditions prosthesis assembly.

Fig. 3. Positioning, loading and boundary conditions of the prosthesis entirely in CF / PA12 composite.

Force components	Percentage of Gait phase				
	2%	13%	19%	50%	63%
F_x [N]	-592.26	-760.5	-774	-672.75	-193.275
F_y [N]	83.62	-310.5	-177.75	472.5	19.32
F_z [N]	- 548.89	- 1532.25	- 1484.77	-1568.25	- 596.25

Table 2. Variation of static forces applied to the prosthesis according to the different positions of the Gait cycle during normal walking.

For dynamic analysis the climbing stairs activity leads to greater forces, of the order of 300 to 600% body weight (J.U. Perez, 2012), we choose the climbing stairs activity in our dynamic analysis, because the hip joint is more solicited. 600% of the body weight was considered as a dynamic force, The given function curve traced by the dynamic force was sinusoidal in shape in order to mimic human walking gait loading patterns on the hip joint (E. Rahim, 2010) as showed in (figure4).

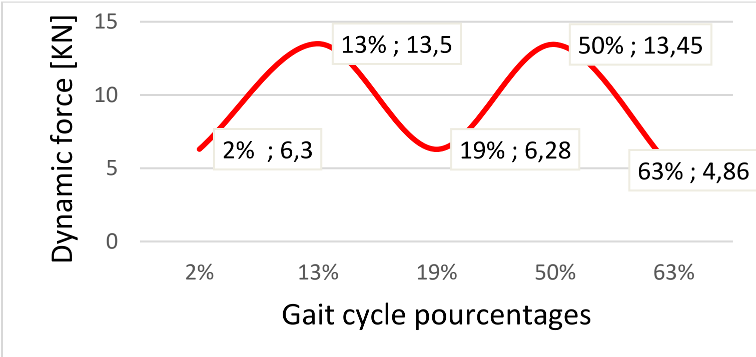


Fig. 4. Dynamic load application on CF / PA12 Hip resurfacing prosthesis for climbing stairs activity.

This dynamic analysis was carried out on CF/PA12 composite hip resurfacing prosthesis under repeated compression cyclic at a frequency of 6 Hz, with the same positions of normal walking. The resulting forces components are shown below Table 3.

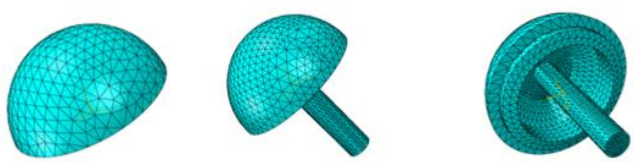
Force components	Percentage of Gait phase				
	2%	13%	19%	50%	63%
F_x [N]	-3553.56	-4563	-4644	-4036.5	-1159.65
F_y [N]	501.72	-1863	-1066.5	2835	115.92
F_z [N]	- 3293.34	- 9193.5	- 8908.62	-9409.5	- 3577.5

Table 3. Variation of dynamic forces applied to the prosthesis according to the different positions of the Gait cycle during climbing stairs.

2.3 Finite element analysis

The finite element analysis was used to compute static, dynamic and fatigue behavior analysis on a hip resurfacing implant entirely made of CF/PA12 composite. This analysis is carried out using the SolidWorks software, compatible with the Abaqus finite element code on a DELL i5, 2.3 GHz Intel (R) processor PC. Cup and femoral components were meshed using a higher order three-dimensional element; SC6R: A 6-node triangular in-plane continuum shell wedge, general-purpose continuum shell, reduced integration with hourglass control, finite membrane strains.

The average number of elements of the acetabular component model is 36407 and 39592 of the femoral head component. Contact elements were used between femoral head and acetabular components surfaces (Figure 5).



(a) meshed cup model (b) meshed head model (c) meshed assembled implant model

Fig. 5. Finite element mesh of Hip prosthesis.

2.4 Fatigue analysis

Dynamic cyclic loading simulation is a way to represent the effect of patient activity on the durability and design of the prosthesis; therefore, the effects of fatigue loads applied to the prosthesis were well illustrated by a dynamic analysis. In this study, the fatigue life of the prosthesis during stress analysis was based on the Goodman mean-stress fatigue theory, the mean stresses σm and alternating stresses σa in the Goodman fatigue life theory are defined by the relations below Eq. (1), Eq. (2) respectively. According to the modified Goodman theory the relation between mean and alternation stress is mentioned Eq. (3), where S_e is the endurance limit and S_{ut} is the ultimate tensile strength of the material. The fatigue factor of safety becomes as Eq. (4).

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2} \tag{1}$$

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2} \tag{2}$$

$$\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}} = \frac{1}{n} \tag{3}$$

$$n_f = \frac{1}{\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}}} \tag{4}$$

2.5 Results and discussion

In this part, the results of the static, cyclic dynamic, and fatigue analysis were described and discussed.

2.5.1 Static analysis results.

The results obtained for the Von Mises stress analysis distribution in the implant was illustrated below (Table 4) and (Figure 6). We found that the highest Von Mises stress are at 13%, 19% and 50% positions (Figure 6). Maximum Von Mises stress values at different positions of the Gait cycle was mentioned below (Table 4).

Different positions of the Gait cycle.	2%	13%	19%	50%	63%
Maximum Von Mises stress [MPA]	4.841	10.630	10.040	10.056	3.798

Table. 4. Static analysis maximum Von Mises stress values.

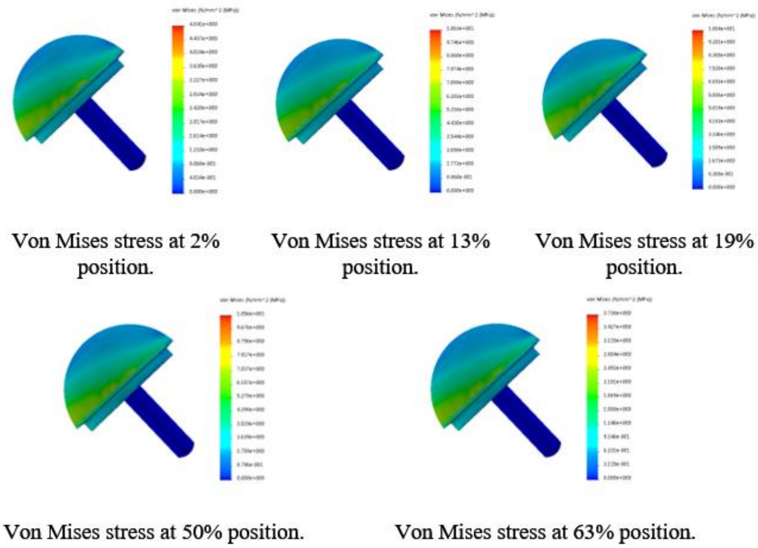


Fig. 6. The static analysis: Von Mises Stress distribution on the CF/PA12 hip resurfacing prosthesis under different levels of stress loading at different positions of the Gait cycle during normal walking.

2.5.2 Static analysis discussions

Highest Von Mises stress are at 13%, 19% and 50% positions (Figure 6), due to the maximum force that will occur at the hip joint at the beginning of the stance phase of the Gait cycle, which is consistent with the literature. Noting that maximum Von Mises stress value 10.63 MPA at the most solicited position of the normal walking cycle is low and does not present any danger for the bone. This indicates that the design is safe using the new CF/PA12 composite material. The maximum of the simulated stresses in the prosthesis depends linearly on the force applied to the assembly, since the contact is continuous between the head and the cup; the contact force depends only on the materials properties and the applied force. We chose the 19% gait cycle position among the positions studied, to see the shape traced by the distribution of the contact surfaces stresses of the prosthesis (outside of the femoral head component and inside of the cup), due to the form which is almost the same in every position, the difference is in the size of this contact surface. The head and the cup being two compliant surfaces, the stresses obtained are distributed over approximately three quarters of the outer surface of the head and the inner surface of the cup as seen in the literature (J.U.Perez, 2012) (Figure 7 a-b).

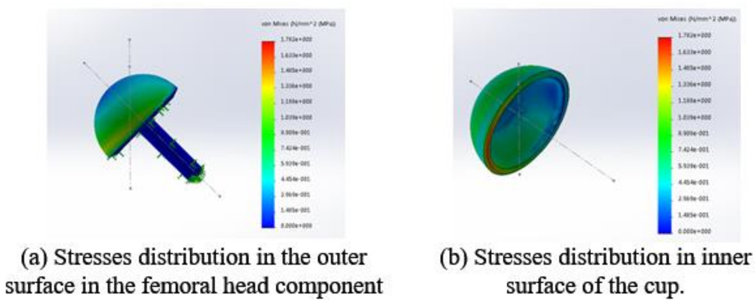
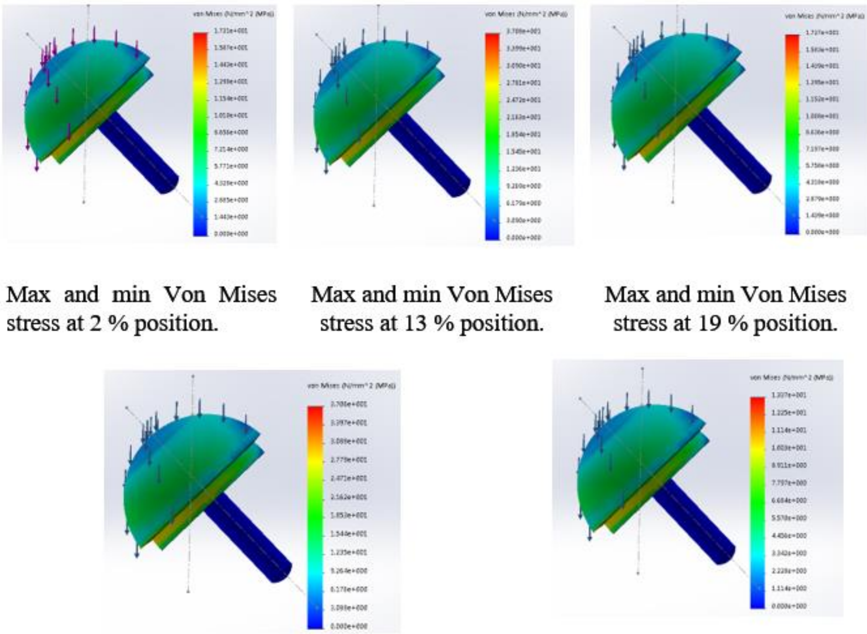


Fig. 7. Stresses distribution in hip resurfacing components.

2.5.3 Dynamic analysis results

The results of the dynamic cyclic analysis during climbing stairs showed the response of the hip joint to a dynamic load condition due to climbing stairs activity. In this analysis, stress concentration areas did not really change, despite the dynamic force applied on the new CF/PA12 composite hip resurfacing prosthesis even in 13% and 50% positions of Gait cycle when the implant is more solicited (Figure.8).



Max and min Von Mises stress at 2 % position.

Max and min Von Mises stress at 13 % position.

Max and min Von Mises stress at 19 % position.

Max and min Von Mises stress at 50% position

Max and min Von Mises stress at 63 % position

Fig. 8. The dynamic cyclic analysis: Von Mises Stress distribution on the CF/PA12 Hip resurfacing prosthesis under different levels of stress loading at different positions of the Gait cycle during climbing stairs.

2.5.4 Dynamic analysis discussions

Two maximum Von Mises stress peaks of 37.08 and 37.06 MPA correspond respectively to 13% and 50% of the Gait cycle positions, are higher than those of the static analysis normal walking for the same positions, this is due to the magnitude of the force applied to the prosthesis during this activity. We confirm that the curve obtained represents two stress peaks at 13% and 50% positions of the Gait cycle similar to that seen in the literature (Hausselle 2007), which proves that our obtained results are reliable (Figure 9).

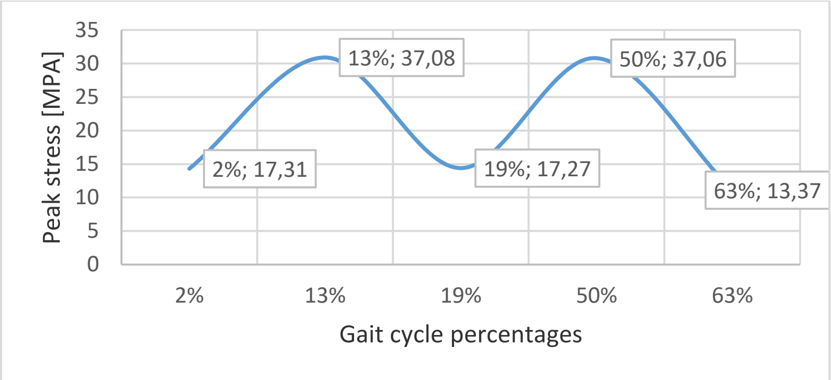


Fig. 9. Dynamic cyclic analysis distribution of maximum Von Mises stress in CF / PA12 Hip resurfacing prosthesis for climbing stairs activity.

Von Mises stress distribution in the Hip resurfacing prosthesis entirely made of CF/PA12 composite solicited by static and dynamic cyclic loads is shown below (Figure 10). From the comparison, we noticed that dynamic cyclic loading generates higher stresses compared to static loading. The peak stresses in the CF/PA12 hip resurfacing solicited by dynamic loads climbing stairs are the highest, around 37.08 MPA and 37.06 MPA at 13% and 50% percentages of the Gait cycle, while for that solicited by static loads normal walking are of the order of 10.630 MPA and 10.056 MPA for the same positions respectively. For 13% and 50% gait cycle positions in the static analysis they both represent the unipodal support of normal walking, and the forces corresponding to these two positions represent the two almost equal and highest values of the force applied on the hip, but the range between the value of the force corresponding to the unipodal support and the value of the force corresponding to the bipodal support in a normal walking is tight compared to this range in the climbing stairs because the peak force would be 23% higher during climbing stairs than during normal walking (Perez 2012). Von Mises stress distribution results obtained under dynamic cyclic loads are 13.31 MPA, 17.27 MPA and 13.37 MPA correspond to 2%, 19% and 63% percentages of the Gait cycle respectively, we notice that these values are close because these three positions represent the bipodal support of the gait cycle. Despite the fact that the maximum Von Mises stresses are higher in the case of the dynamic cyclic load, they are still low compared with limit stress. Which is an advantage for the durability of the prosthesis and also for the bone. A low concentration of stress on the prosthesis will reduce the stress concentration generated by the implant on the bone, which reduces its risk of fracture.

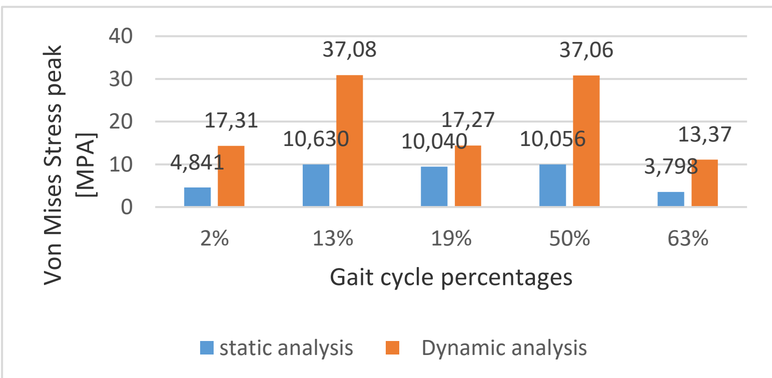
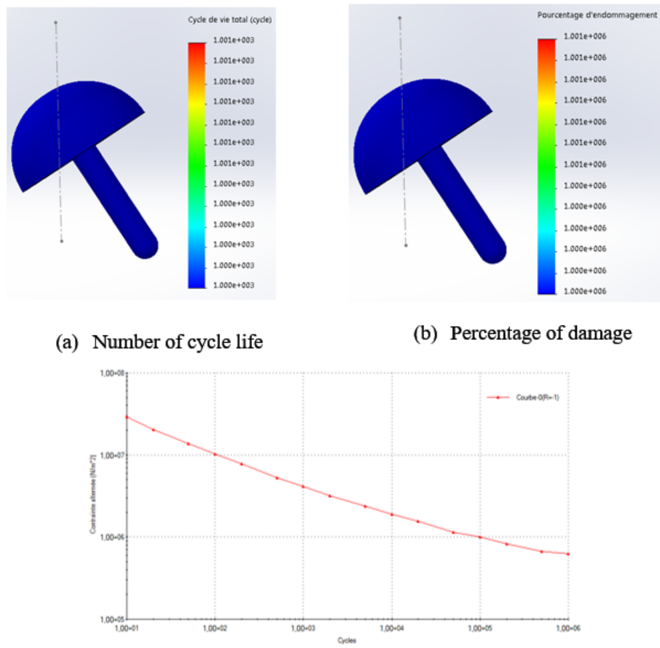


Fig. 10. Comparison of results of each position for each load approach analysis

2.5.5 Fatigue analysis results and discussions

Von Misses stresses obtained from finite element analyses are utilized in fatigue life calculations. All fatigue analyses are performed according to infinite life criteria ($N=10^9$ cycles).

Static and dynamic cyclic analyses of the prosthesis should be conducted to ensure about long lifetime of the design. Prostheses are often designed according to the results of static analysis. Static finite element analyses are mostly conducted under body weight loads. However, dynamic effects may add up to about 10–20% or more loading to the prosthesis, which must be taken into account not to cause fracture or fatigue failure of the prosthesis. In our case of dynamic study, we consider climbing stairs activity with 600% of the body weight as a dynamic force. Based on static and dynamic cyclic analysis results of our resurfacing prosthesis designed entirely in CF / PA12 composite, conduct to predict that given low maximum stresses observed on our proposed prosthesis are far from the elastic limit (Figure 7-9), which is around 2500 to 3200 MPA. Whatever solicitations intensity that the prosthesis might undergo during daily human activities, it will never be exposed to failure. By synthesis two main works, that of Wen Zhang and al. (2010) who did a comparative finite element analysis showing lifetime predictions of alumina and silicon nitride as ceramic materials for the hip resurfacing prosthesis under the same boundary conditions and static loading. The lifetime predictions showed that silicon nitride is indeed mechanically reliable and ideal for hip resurfacing prostheses. With our study, we want to develop this resurfacing prosthesis by changing the ceramic material that is fragile with the CF / PA12 composite that resists to rupture by performing fatigue analysis under dynamic load (Figure 11). Based on the results mentioned above, our CF / PA12 prosthesis is very far from fatigue and we consider it as a better alternative to silicon nitride hip resurfacing prosthesis. Comparing our approach with the second study of Campbell, Bureau and Yahia (2008), their paper presents a thorough analysis of the mechanical properties and an evaluation of the performance of this innovative composite design for femoral stems made from a carbon-fiber reinforced polymer composite. Both short and long term mechanical testing of the hip stem were discussed in detail during their work. As a conclusion drawn from this work, the bone-matching properties of this composite-made total hip prosthesis and its excellent fatigue performance (Figure 11), by far surpassing required fatigue life make CF/PA12 candidate material of choice for orthopedic devices such as total hip prostheses and might offer a long-term solution to stress shielding and bone desorption. The fatigue analysis behavior in their study is done on a total hip prosthesis stem, which gave us the idea to do a finite element fatigue analysis on a resurfacing prosthesis fully made (head and cup components) from this material. Our results confirm that the reliability of our prosthesis.CF/PA12 composite hip resurfacing prosthesis is really far from fatigue and failure risk.



(a) Number of cycle life

(b) Percentage of damage

(c) S-N fatigue curve analysis

Fig. 11. Fatigue approach analysis

This plot (Figure 11), represents the percentage of the life of the structure consumed by the defined fatigue events (cycles= 10^7).

3. Conclusion

This paper investigated static and dynamic behavior analysis of the proposed hip resurfacing prosthesis entirely designed with new CF/PA12 composite to conduct to determine the fatigue life of the prosthesis during stress analysis in case of walking and climbing stairs activity. We have focused our analysis on the couple composite / composite hip resurfacing prosthesis. Based on static and dynamic finite element analysis results, maximum Von Mises Stresses were calculated. The outcomes showed that maximum stresses on CF/PA12 composite prosthesis were low under static loading. The effects of the fatigue loads applied on the CF/PA12 composite hip resurfacing due to climbing stairs are well illustrated by dynamic cyclic analysis. So, under dynamic loading. The maximum stresses obtained were still low and so far from the yield stress, these indicate that the hip resurfacing prosthesis fully designed with CF/PA12 composite material is safe against fatigue under dynamic repetitive loadings. This fatigue performance of our hip resurfacing prosthesis entirely designed with CF/PA12 composite confirms that it is among the most appropriate implants for hip replacement. However, the finite element model needs to be improved, such as inclusion of surfaces conditions of the prosthesis components (roughness) would be expected to ensure better osseointegration.

The recommendations made following the work of this paper consist in optimizing the CF / PA12 hip resurfacing stem and cup geometric shape and their surface condition to improve osseointegration and stability of the implant.

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