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Research Article

COMPARATIVE ANALYSIS OF THE MECHANICAL BEHAVIOR OF THREE VOLUTE FORMS OF CENTRIFUGAL PUMP

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ABSTRACT

This paper presents a comparative-based analysis on the mechanical behavior of three different forms of volute of volute of a centrifugal pump with a spline, a radial and a tangential type using ABAQUS Software calculation code. The result of the analysis shows that the stress concentration is localized at the volute nozzle for all the three types of forms. This founding is an interesting element as regards to the possibilities of adaptation of a pump to a particular operation. Also, it is found that the tangential volute is the least stressed compared to the other two forms. The displacements are more pronounced in the case of a radial volute. These data can be exploited in order to predict the possibility of accidental rupture of this element. From another point of view this can have an indirect influence on the appearance of vibration, noise and fluctuations of pressures and speeds due to the interaction between the fixed part (volute) and the mobile part (impeller).

Keywords: centrifugal pump; spline volute; radial volute; tangential volute.

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1. INTRODUCTION

The centrifugal pump is a device that draws fluid from a low-pressure region to deliver it to a higher-pressure region. The increase in the pressure of the liquid conveyed by the pump takes place following the transformation of the mechanical energy supplied by a motor driving this pump into an increase in the hydraulic energy which is acquired by the liquid between the inlet and the pump outlet. Receiving the flow at the outlet of the pipe, the volute must transmit the most homogeneous flow as possible over the entire periphery of the pre-distributor with the minimum of internal losses. The difficulty comes from the fact that the flow at the entrance of the volute is of the type Cu = *cte* but it quickly reverses to a flow of the type $RCu = cte$ due to the general curvature of the volute. The angles of attack on the distributor front obviously differ depending on whether they are governed by one or the other of these laws. Several works were carried out on the subject and more particularly the studies focusing on the optimizing of the performance of centrifugal pumps. We cite as significant some works which could serve as a guide in this study such as: the volute tracing methods carried out by Claude Moulin [1]. The work proposed by D. Descamps et al. [2] which consisted in studying the influence of the volute nozzle on the noise generated by a centrifugal pump. The influence of the tangential volute shape of a centrifugal pump on the structure of the internal flow which was the subject of the work of A. Allali et al. [3]. The design of a centrifugal scroll pumps to obtain the best performance point which has been carried out and analyzed by Ravi Shastri et al. [4]. The case of Newtonian (water) and non-Newtonian fluid (using the power law model) were examined in order to see their effects on the properties and parameters of internal flux in three forms of volutes made by A. Allali et al. [5]. The effects of the design of the volute and the number of blades on the lateral forces of the impeller and the hydraulic performance which have been approached by Daniel O. Baun et al. [6]. S. Belbachir et al. [7] numerically simulated the distribution of Von Mises stresses and displacements in volutes of different dimensions in diameter and width of a centrifugal pump. The work of PV Shyam et al. [8] who were able to generate cross-sectional profiles of the volute and thus arrive at the 3D structure of the volute using the Mathcad tool capable of designing different types of compressors scrolls industrial air. The geometry generated integrates the manufacturing and performance requirements necessary for a practical design of the volute. Regarding the work proposed in this article, we turned to a comparative study between the mechanical behaviors of three volute forms of a centrifugal pump using Abaqus software.

2. VOLUTE DRAWING METHODS

Receiving the flow at the outlet of the pipe, the volute must transmit the most homogeneous flow possible over the entire periphery of the pre-distributor with the minimum of internal losses as possible. The various volute sections are crossed by a fraction of the pump flow, a fraction depending on the angular position of the section relative to the volute nozzle. The layout of the sections is generally limited to the point of maximum efficiency (nominal flow). Conventionally the values of the areas of the sections are determined by one-dimensional methods which consider only an average flow in the volute, namely:

Either, the method based on the principle of the conservation of the mass angular momentum by taking into account the effects of friction.

Or, the method based on the conservation of the average velocity of the flow in the volute (the fluid threads feeding the downstream end of the volute do not undergo the same pressure drop as the threads feeding the first sections of this volute).

3. CONFIGURATIONS, BOUNDARY CONDITIONS AND LOADING

a) The fixed end was taken at the level of the outlet section of the rotor which represents the inlet of the volute.

b) The load was uniformly applied to the entire internal surface of the volute in the form of a pressure with a value of 25 bars.

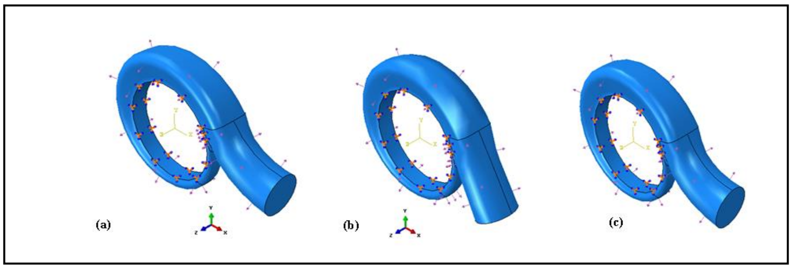

Fig.1. Loading and boundary conditions: (a) Radial volute; (b) Tangential volute; (c) spline Volute

4. PROPERTIES OF THE MATERIALS

The volute is made of cast iron. The definition of material properties has been declared in the ‘’ Property’’ module.

Table 1. Mechanical properties of cast iron

General Properties of Cast Iron FGS -400-15	Values
Young's module E	165000MPa
Poisson coefficient υ	0,3
Elastic limit	250MPa
Rupture strength	400MPa
Density	7200kg/m^3
Modulus of rigidity G	56GPa

Table 1 shows the mechanical characteristics of the cast iron.

5. MESH OF THE MODEL

The mesh used is of a linear tetrahedral volume elements type with 4 nodes. In this volume element, no simplifying assumptions were made on the strains and the stresses.

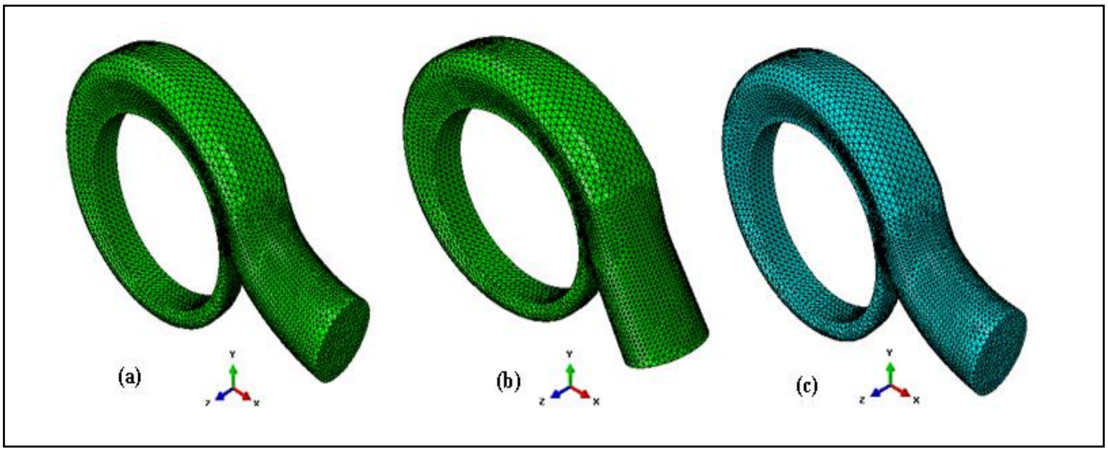

Fig.2. Meshing: (a) Radial volute; (b) Tangential volute; (c) Spline Volute

6. RESULT AND DISCUSSION

Simulation of the mechanical behavior in static regime of the three forms of volute of a centrifugal pump was carried out. From the illustrations of the stress and displacement distributions for the three forms of volute, the following results can be drawn:

6.1. Von Mises stress fields

Under pressure load, the volute is subject to mechanical stresses which can be high. If these stresses exceed the limit resistance to fracture of the cast iron chosen as the volute material a rupture will occur (Figure 3).

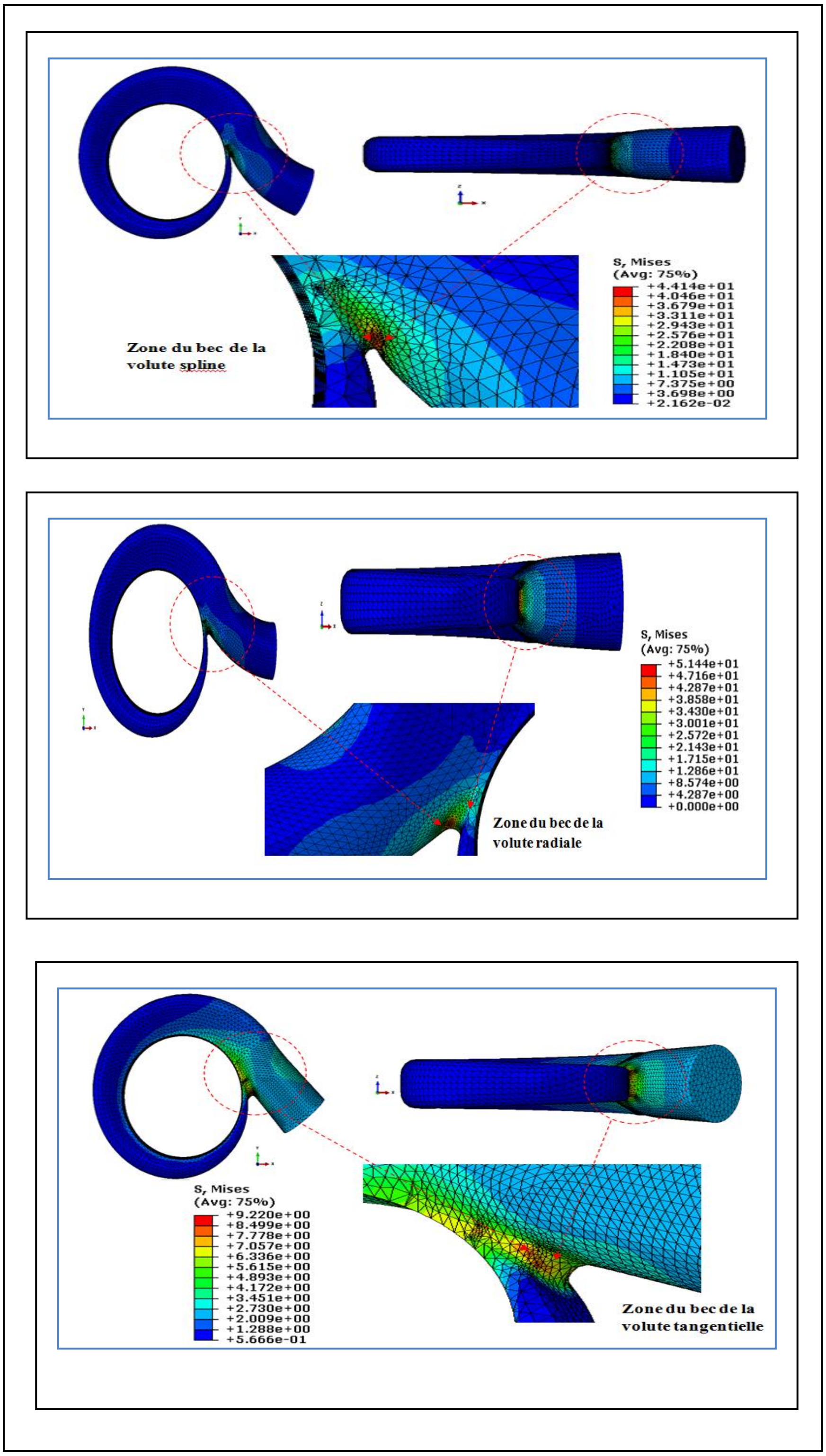

Fig.3. Von Mises' stress Contour for different views of the volute

From the observation on the maximum Von Mises' distribution stress contours, it can be noticed the localisation of these constraints at the nozzle for all the forms of volute.

While consulting the distribution contours of maximum stresses of Von Mises for the three cases, we were able to note a localization of these constraints at the level of the beak for all the forms of volute. The trends in the distributions of the Von Mises' stresses in the three forms of volutes are similar. In all the cases studied, the volutes work in the elastic domain in complete safety since the maximum Von Mises' stresses do not exceed the elastic limit of the cast iron. It was noted that the radial type volute is the most stressed with a maximum stress of 51.44 MPa compared to the tangential volute which is lower and equal to 9.22MPa. We can say that the hazard zone of the volute is at the nozzle.

6.2. Displacement fields

The contours of the displacements in the centrifugal pump volutes are illustrated in Figure 4. The displacements, due to pressure loading, were examined by changing the shape of the volute. Generally, the displacement distribution is not uniform. The values of these displacements at the outlet of the volute are greater than those of the remaining part due to the distribution of the load and the fixed end. The contours of the displacement distribution for the three volutes are almost similar. The displacement of the radial volute is higher compared to the tangential and spline forms of the volutes.

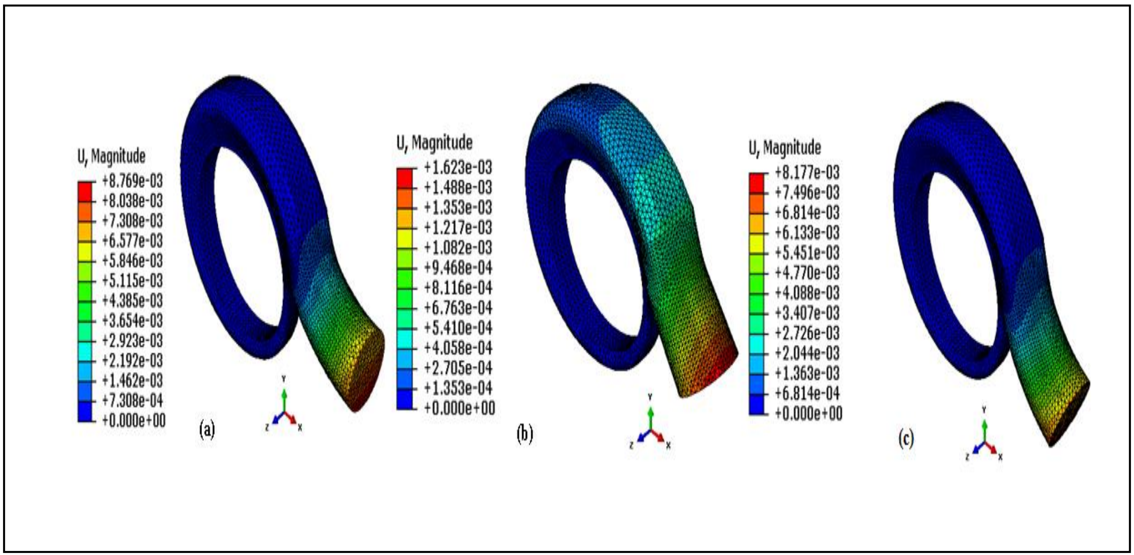

Fig.4. Displacement contour :(a) Radial volute; (b) Tangential volute; (c) spline Volute

7. CONCLUSION

A comparison of the mechanical behavior of three types of volutes of different shapes working with the same wheel was investigated. The stresses, strains and displacements distributions were analyzed. The maximum values are not the same for the three forms of volute. The tangential volute is the least stressed and thus resists much better compared to the tangential and spline forms of the volutes.

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