Unsteady Flow Induced Pressure Pulsation and Vibration in a Centrifugal Pump

Bo Gao, School of energy and power engineering, Jiangsu University Zhenjiang, China
Zhen Wang, School of energy and power engineering, Jiangsu University Zhenjiang, China
Ning Zhang, School of energy and power engineering, Jiangsu University Zhenjiang, China
Li Yang, School of energy and power engineering, Jiangsu University Zhenjiang, China
Wenqaing Du, School of energy and power engineering, Jiangsu University Zhenjiang, China

Long Abstract

Introduction

The flow inside a centrifugal pump is always unsteady caused by several mechanisms. It is also responsible for unsteady dynamic load on pump impeller and casing which leads to pump vibration and noise. Lots of studies have been conducted on the unsteady flow phenomenon in centrifugal pumps with volute casings during the past two decades, such as rotor-stator interaction induced internal flow field and pressure pulsation, radial dynamic forces on impeller blades. Pump vibration and noise have also been studied by numerical and experimental methods. Pump vibration performance with different operating conditions have been understood. However, few studies are on relations between the flow-dynamic excitation and detailed vibration spectrum characteristics. In order to explain the fluid-dynamic excitation induced vibration, the transient flow simulation, pressure pulsation measurement and special pump casing vibration test were conducted in a centrifugal pump.

1. Methods

The structural mesh and turbulence model were used based on the comparing results of different calculation approaches, to study the unsteady flow characteristic of the whole internal flow field in the pump (Fig.1) to achieve the unsteady excitation characteristic at designed and off-designed conditions. This study focused on the analysis of pressure pulsation at different positions on pump volute casing and the radial forces on each impeller blade.

High frequency pressure sensors (PCB 113B27) were used to measure the static pressure pulsation on pump casing to validate the simulation results (Fig.2). In additional, real pressure fluctuating signals were obtained for further discussions on the contributions in pump vibration performance. Pump casing vibration was tested by LMS SCADAS System with PCB acceleration transducers. Pump vibration are caused by hydrodynamic and mechanical factors. In order to weaken the mechanical influence, special pump assemble method was proposed. Comparing with the normal one, energy difference 6dB was observed between pump casing and support.

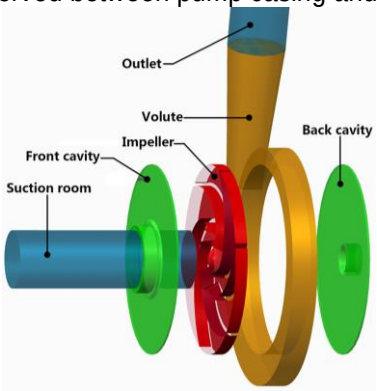

Figure 1. Flow domain in the pump

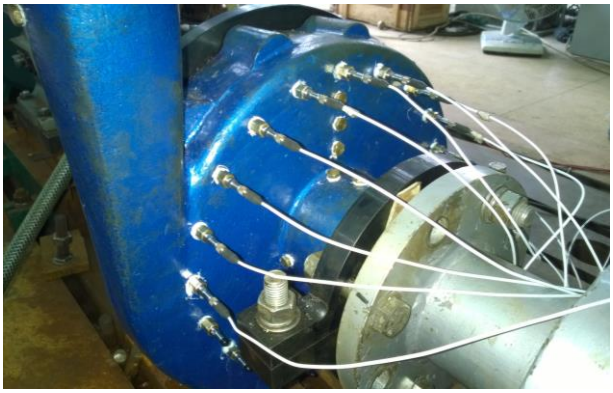

Figure 2. Pressure pulsation and vibration test

2. Conclusions

In this paper, the pressure pulsation characteristic of model pump is acquired by relevant tests. There is different pressure pulsation amplitude at the different pressure monitoring point. And pulsation signals distribute mostly in low frequency band. The shaft frequency and blade passing frequency are dominant at all monitoring points in pressure pulsation spectrum figures. The rate of change at monitoring point P6 which on the tongue is maximum. Severe interaction between wake flow and volute and the small radial gap between impeller and volute at monitoring point P6 is the reason of above phenomenon. It illustrates that flow rate and positon are main factors that induce changing of pressure pulsation. And different monitoring point suffers different effect which is product by rotor-stator interaction and asymmetric structure of volute.

After decoupling test for model pump, under the premise that factor of hydrodynamic factor induced vibration is basically same, the changing of mechanical factor induced vibration transmission route is influential certainly for vibration situation of whole pump in the whole flow operation process. Especially, it is influential enormously for induced high frequency vibration. The tests about pump decoupling could validate that it does abate the cause of mechanical vibration in centrifugal pump in a certain degree. This result could provide a basis for improving stable operation in centrifugal pump.

References

[1] Spence R, Amaral-Teixeira J, A CFD parametric study of geometrical variations on the pressure pulsations and performance characteristics of a centrifugal pump[J] Compute Fluids, 38 (2009) 1243–1257.

[2] Majidi K, Numerical study of unsteady flow in a centrifugal pump[J]. ASME Journal of Turbo-machinery, 2005,127:363-371

[3] Lucius A, Brenner G. Unsteady CFD Simulation of a Part Load Conditions Using Scale-Adaptive Simulation. International Journal of Heat and Fluid Flow, 2008,29(5): 1527-1540.

[4] Daniel O. Baun, Kostner L, Ronald D. Flack. Effect of Relative Impeller-to-Volute Position on Hydraulic Efficiency and Static Radial Force Distribution in a Circular Volute Centrifugal Pump[J]. Journal of Fluids Engineering, 112(2000)598- 605.

[5] Barrio R, Parrondo J, Blanco E, Numerical analysis of the unsteady flow in the near-tongue region in a volute-type centrifugal pump for different operating points. Compute Fluids, 39 (2010) 859–870.

[6] B. P. M van Esch. Performance and Radial Loading of a Mixed-flow Pump Under Non-Uniform Suction Flow[J]. Journal of Fluids Engineering, 131(2009)11-17.

[7] Barrio R, Fernandez J, BlancoE, et al. Estimation of radial load in centrifugal pumps using computational fluid dynamics[J]. European Journal of Mechanics B/Fluids. 2011

[8] Ning Zhang, Minguan Yang, Gao Bo, et al. Unsteady Phenomena Induced Pressure Pulsation and Radial Load in a Centrifugal Pump with Slope Volute. ASME - FEDSM 2013 , NEVADA,7-11July