Computational Fluid Dynamics Calibration of Tattersall MK-II Type Rheometer for Concrete

H.D. Le[1,2*], G. De Schutter[1], E.H. Kadri[2], S. Aggoun[2], J. Vierendeels[4], S. Tichko[1,3], and P. Troch[3]

[1] Magnel Laboratory for Concrete Research, Department of Structural Engineering, Ghent University, 9000 Ghent, Belgium
[2] Laboratory for Mechanics and Materials in Civil Engineering, Department of Civil Engineering, Unit of Formation and Research Science and Technology, Cergy-Pontoise University, 95000 Pontoise, France
[3] Hydraulics Laboratory, Department of Civil Engineering, Ghent University,9000 Ghent, Belgium
[4] Department of Flow, Heat and Combustion Mechanics, Ghent University, 9000 Ghent, Belgium

*Corresponding author: haidang.le@ugent.be
Fax: x32.9.245845

Received: 1.10.2012, Final version: 21.2.2013

Abstract:
Currently more and more researches have been performing concerning the numerical simulation of the behavior of fresh concrete during pumping or formwork filling. Adequate implementation of the rheology properties of fresh concrete is a determinant key to obtain realistic simulations. However, in many cases, the rheological parameters of the fresh concrete as determined by rheometers are not sufficiently accurate. The common principle of all the rheometers is not to measure directly the rheological parameters of concrete but to measure some basic physical parameters (torque, velocity, pressure, ...) that that in some cases allow the calculation of the rheological parameter in terms of fundamental physical quantities. Errors can be caused by undesired flow phenomena which are not taken into the prediction formulas and by the inaccurate prediction formulas themselves. This is directly related to the poor calibration of the rheometer that cannot cover all ranges of materials. This paper investigates the calibration of the Tattersall MK-II rheometer by performing the numerical simulation for a tremendous range of concrete flowing in the rheometer, using computational fluid dynamics (CFD). This allows to quickly and accurately obtain the rheological properties of fresh concrete, which can then be used consistently for further flow simulations. This method can be applied for all types of rheometer.

Zusammenfassung:
Gegenwärtig werden immer mehr Arbeiten über die numerische Simulation des Verhaltens frischen Betons während des Pump- oder Füllvorganges bei der Schalung durchgeführt. Eine adäquate Implementation der rheologischen Eigenschaften des frischen Betons ist essentiell, um realistische Simulationen durchzuführen. Jedoch sind die rheologischen Größen des frischen Betons, die mittels rheometrischer Messungen erhalten wurden, in vielen Fällen nicht ausreichend genau. Das gemeinsame Prinzip aller Rheometer besteht darin, nicht direkt die rheologischen Parameter des Betons zu messen. Statt dessen werden einige grundlegende physikalische Größen (Drehmoment, Geschwindigkeit, Druck, ...) ermittelt, die in einigen Fällen erlauben, die rheologischen Parameter mit Hilfe fundamentaler physikalischer Größen zu berechnen. Fehler können dabei durch nicht gewünschte Strömungsphänomene verursacht werden, die in den Formeln nicht berücksichtigt werden. Dies wird direkt in den Zusammenhang mit der mangelhaften Kalibrierung von Rheometern gebracht, die nicht den gesamten Materialbereich erfassen kann. In dieser Arbeit wird die Kalibrierung eines Tattersall MK-II-Rheometers untersucht. Dabei werden numerische Computational Fluid Dynamics (CFD)-Simulationen über einen sehr großen Bereich einer Betonströmung in dem Rheometer durchgeführt. Dies erlaubt, schnell und genau die rheologischen Eigenschaften vom frischen Beton zu gewinnen, die für weitere Strömungssimulationen verwendet werden können. Diese Methode kann auf alle Rheometer angewandt werden.

Résumé:
De nos jours, des simulations numériques du comportement du ciment frais durant le pompage et le remplissage de pré-formes sont de plus en plus entreprises. L'implémentation correcte des propriétés rhéologiques du ciment frais est la clé déterminante afin d'obtenir des simulations réalistes. Cependant, dans beaucoup de cas, les paramètres rhéologiques obtenus à l'aide de rhéomètres ne sont pas suffisamment précis. Le principe commun de tous les rhéomètres n'est pas de mesurer directement les paramètres rhéologiques du ciment, mais de mesurer des paramètres physiques basiques (torsion, vitesse, paramètres rhéologiques sous forme de quantités physiques fondamentales. Les sources d'erreurs peuvent provenir de phénomènes d'écoulement non désirés qui ne sont pas

 DOI: 10.3933/ApplRheol-23-34741

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torque thickening is observed with n = 2.1 (Figure 15). Of course, this phenomenon cannot be observed in the reality because the torque value is too small to be captured and is neglected regarding the internal friction of the rheometer. It confirms that the modified Herschel-Bulkley is not the cause of the false shear thickening, the false shear thinning and the underestimating n index phenomena. False shear thickening, false shear thinning and n index underestimation as mentioned above are taken into account when applying the mathematical regression modeling.

7 CONCLUSION

In order to measure accurately the rheological properties of cement based materials with the Tattersall rheometer – a coaxial rheometer –, a numerical method has been developed. This method consists of simulating the operation of the rheometer with a wide range of known rheological fluid properties to obtain the relationship between the flow curve and the torque-speed curve. In order to use this relationship to accurately calculate the flow curve from the torque-speed curve of any unknown rheological properties fluid, this relationship has been modeled by doing mathematical fitting. The models obtained allow the employment of the method to be done quickly and accuracy. In order to investigate the accuracy of the method, an experimental comparison has been carried out between the Tattersall MK-II rheometer and the Anton Paar MCR52 rheometer which is a mortar rheometer having available formula to calculate the shear stress and shear rate. The comparison shows completely consistent results for the two rheometers. This method can be applied to other types of rheometer with complex geometry because it allows to take into account almost all of the potential errors including the end effect, the plug flow effect, the 3D flow of fluid through the blades and the vacuum zone behind the blades. Regarding its ability to get rid of the gravity-induced segregation, the Tattersall MK-II rheometer can be a quite polyvalent rheometer that can work for both concrete and mortar. However, the modeling does not perfectly fit for some cases of materials. As a consequence, an error is resulting. This error can be minimized by improving the mathematical fitting formula in future research.

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