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Prof. dr hab. inż. Marcin Perzyk
Wydział Inżynierii Produkcji
Politechnika Warszawska
Narbutta 85, 02-524 Warszawa
Tel.: 509093935
E-mail: mperzyk@wip.pw.edu.pl

Review of PhD Thesis submitted by

mgr inż. **Rafał Dojka**

entitled „Investigation on the gating system: Reoxidation in the mould"

1. Rewiew and evaluation of the subject of the dissertation

The reviewed doctoral dissertation is devoted to the topic of designing the most important elements of foundry technologies, which are the gating systems. The key significance of this issue results from two main factors: firstly, the fact that most of the casting defects arise as a result of the improper filling of the mould cavity, and secondly, from the current high and constantly growing requirements regarding the properties and quality of castings, especially their strength, favouring the design of lighter products. The dissertation is of a research nature, for the most part utilizing computational methods in the form of so-called numerical experiments, although real experimental research also plays a vital role.

Shaping the gating systems was the main research problem and achievement of many years' work of the most outstanding person in the contemporary world of foundry engineering, the British professor Sir John Campbell, who obtained his knighthood for the achievements in this field. His discoveries related to the formation and behaviour of the bifilms led to a completely new view on the process of mould filling and redefined the approach to gating systems design. The reviewed doctoral

dissertation is, in essence, not only inspired by his works but constitutes their further development and significant implementation in the form of extremely valuable recommendations regarding the design of gating systems for ferrous alloys.

2. The most important advantages and achievements of work

Doctoral thesis of mgr inż. Rafał Dojka is in the opinion of the reviewer a very significant scientific and technical achievement. The most important features that form the basis of this statement are listed and discussed below.

- Exceptional comprehensiveness and depth of analysis of a complex scientific and technical problem. Particularly a very good literature overview of the research problem, thorough knowledge of the foundations of modelling of phenomena occurring in the mould during the filling, as well as practical methods and tools used for numerical simulation of the flow of liquid metal with various types of inclusions, leading to filling the mould cavity and solidification. Particularly noteworthy is the use of virtually all the numerous advanced and sometimes even sophisticated capabilities of the applied simulation software, provided by leading global companies. They include various types of criteria for assessing the mould filling process such as the amount of air entrapped in metal, the size of the free surface forming during flow, the average velocity of the metal stream in the ingates, as well as three different similarity numbers characterizing the flow. The complexity of the PhD student's work is also reflected in taking into account both the most advanced and yet little-known types of gating systems (e.g. 'vortex' and 'trident gates'), as well as systematic examination of various types of gating system's channel geometry (cross-sections and lengths of individual segments), including innovative ones with the shape of flat rectangles.
- Obtainment of specific, very valuable information on optimal designs of gating systems components based on the natural pressure distribution. Favourable

profiling of sprue using the hyperbolic shape has been proven. The performance of the runner equipped with a spin trap, i.e. the final space for collecting contaminants with the shape enabling the swirling motion of the metal stream and, as a consequence, avoiding the return wave, was comprehensively tested. Thanks to the work of Rafał Dojka, this type of solution suggested by prof. Campbell has not only been tested but also optimized and can be implemented in many practical cases. A very valuable and, in my opinion, crucial discovery of the author is that the best shapes of the gating system channels cross-sections are thin rectangular rectangulars. His work also brings many further valuable practical recommendations.

- Development and examination of a new type of fluidity test, in two variants, including flat channels of rectangular cross-sections resulting from previous tests and analyses carried out by the author. It should be emphasised that the author presented deep and insightful reasoning in designing these tests which is rarely encountered.
- Very interesting and well justified radiographic analysis results. Particularly noteworthy are the observations of shrinkage cavities connected with the bifilms and air bubbles created as a result of flow turbulence. The author's interpretation and the resultant conclusions can be valuable for simulation software developers.
- Very interesting results of metallographic analysis aimed at confirming the presence of bifilms in solidified castings, allowing for quasi-quantitative assessment of their quantity and bringing interesting illustrations of various forms of these inclusions.
- The clear and logical layout of the dissertation text, which is the result of the author's correct, insightful and comprehensive way of thinking, leading to the specification of the the main and detailed actions plan, performed within his work. This text contains very few editing and language errors.

3. A critical assessment of the dissertation

According to the reviewer, the work reveals some of the shortcomings and brings about some disputable statements, listed below.

1. The term 'reoxidation' appearing in the title of the dissertation, as being the main subject of the scientific research presented in it, has not been explicitly and precisely defined. Also it is not a commonly known and used term in the sense as it occurs in the dissertation. In the text it does not appear till page 27 and not in the definition, but in a way on the occasion of a certain statement appearing in one of the cited works. The very meaning of the word 'reoxidation', i.e. 'secondary oxidation', does not fully explain the context of its use in the dissertation. Doubts may also arise as to whether some phenomena that are a key element of the subject of the dissertation must be the result of some secondary oxidation of the metal: after all, 'bifilm' can be an oxide film present from the beginning of the melting process on the surface of a metal in a furnace or ladle, and it also may consist of other impurities, than oxides.

2. The dissertation lacks justification for the plan of some research works and choice of the methods used in them. This applies, for example, to the selected types of alloys and certain geometry parameters (e.g. height of the sprue or ignoring horizontal ingates in the study), as well as the general plan of the simulation experriments. It is particularly important in view of the truthfulness of author's statement: "*it is important to realize that almost no simulation software can simulate the presence of small bubbles and bifilms.*" Another, quite important example of the lack of justification of the adopted research methods is the use of the Weibull analysis to assess the degree of variation in the mechanical properties of the alloy in the castings due to the use of various gating systems. The author considers this approach (proposed by Prof. Campbell) as obvious, however, despite its undoubted advantages and innovative view, it is not widely used. I think that more common statistical tools

used in such cases, like analysis of variance or nonparametric, universal Kruskal-Wallis test should be also considered.

3. Both theses formulated in the dissertation are, according to the reviewer, obvious statements and are simply a concisely expressed current state of knowledge. They should only be treated as reasons for addressing the topic, not theses which are the theorems which should be proved in the dissertation.

4. The work does not refer to the problems of gating systems design for alloys that are particularly prone to oxidizing (e.g. aluminium or magnesium). I do not mean that the research in this field should be also included in the dissertation (in which a lot of work was done by the author), but it would be desirable to indicate potential differences concerning the main groups of cast alloys as well as the need and possible directions of further work. This would be not only desirable but also, in a sense, natural as the entire research program related to the occurrence of bifilms and air bubbles trapped in the cast material has its roots in aluminium alloys casting.

5. The dissertation lacked precise determination of some geometrical parameters (e.g. in the form of drawings). In particular this applies to the angle of inclination of the flow, which is "*in the author's opinion the most important variable that should be analysed in the mass flow diagrams ...*". There was also no presentation of the exact shape of the minimum section of the choke, although a lot of attention was paid to its role; the reference to the right side of Figure 38 showing the metal flow is insufficient.

It should be strongly emphasized that the above-mentioned critical remarks do not depreciate the aforementioned main achievements of the dissertation. The reviewer hopes that they can be an inspiration and aid in the author's further professional and scientific activities.

4. Summary of the review and conclusion

The reviewed dissertation is undoubtedly an extremely valuable solution to an important industrial and scientific problem in which modern research methods have been used and the analyses have been carried out at a very high substantive level. Thanks to the obtained results, we know that it is possible to design gating systems for ferrous alloys that can ensure high, stable casting strength and, importantly, we know how to do it. According to the reviewer, the dissertation represents the author's extremely high intellectual level combined with the practicism of the researcher and engineer. In the context of other works that are known to me from similar research areas, I consider its level to be distinctive.

Considering the above, as well as the fact that the PhD student has demonstrated appropriate theoretical knowledge in the scientific discipline of Material Engineering and proved the ability to conduct research independently, I believe that the doctoral dissertation of mgr inż. Rafał Dojka meets the requirements of the Act on academic degrees and academic title and on degrees and title in the field of art dated on March 14, 2003, as amended. Therefore, I am recommending acceptance of the thesis for public defence. Moreover, I am nominating the dissertation for the distinction for the outstanding contribution to the Material Engineering discipline.