UNIVERSITY OF AMSTERDAM

UvA-DARE (Digital Academic Repository)

Casting Rodin's Thinker

Sand mould casting, the case of the Laren Thinker and conservation treatment innovation

Beentjes, T.P.C.

Publication date
2019

Document Version
Other version

License
Other

Link to publication

Citation for published version (APA):
Beentjes, T. P. C. (2019). *Casting Rodin's Thinker: Sand mould casting, the case of the Laren Thinker and conservation treatment innovation*. [Thesis, fully internal, Universiteit van Amsterdam].

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: https://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, P.O. Box 19185, 1000 GD Amsterdam, The Netherlands. You will be contacted as soon as possible.

UvA-DARE is a service provided by the library of the University of Amsterdam (https://dare.uva.nl)

Download date:13 Nov 2026

Introduction

In the night of the 16th to 17th January 2007, a bronze statue by Auguste Rodin (1840-1917), the *Thinker*, disappeared from the sculpture garden of the Singer Museum in Laren, the Netherlands. Only days after the theft, the bronze was retrieved, albeit heavily damaged. After heated debates in public media and within multiple committees and advisory bodies, the management of the museum, after long and careful deliberation, decided to have possible treatment options for the mutilated bronze investigated and approached the author at the Metal Conservation Programme at the University of Amsterdam for that reason. The importance of the sculpture and the severity and complexity of the damage inflicted, required a scientific approach whereby the conservation treatment was research driven. Because traditional restoration methods were deemed unsuitable, an innovative approach was required.

Before commencing a treatment, one tries to comprehend the changes to an object, to make an informed judgement regarding its current condition and possible treatment. An historic object has often been described as a historical document, a carrier of historical information. Some of this information is readily visible while other information requires advanced analytical research and an experienced eye. There is an increased awareness of the art-technological aspects of cultural heritage whereby new analytical techniques such as neutron tomography, MA-XRF scanning and isotope analysis help us to understand objects better.

As a conservator, with an initial training as gold and silversmith, I have a particular interest in historic metalworking techniques. The practitioner in me is often intrigued by the intricacies of the manual process. However, these aspects of a making technique are often lacking in the literature. This lack of specific technical knowledge has several causes: artisans fabricating objects such as bronze sculpture, were often not academically schooled and therefore did not publish their knowledge. They might have taken notes but these rarely survive. Secondly, some of the intricacies of the making processes, artistic as well as reproductive, are not straightforward to convey in words on paper. This knowledge, sometimes labelled as ‘tacit’ or ‘embodied’, was the result of experience, intimate knowledge of materials and skill and conveyed through the execution of the process and not the written word. In terms of modern academic research and its standards, this means there are gaps in our knowledge of art-technological processes.

This is also true in the case of the famous sculptor Auguste Rodin and his work, in particular the series of more than seventy bronze sculptures that became known under the title of *The Thinker* (*Le Penseur*). A great deal of research has been done on the artist Rodin, and many art historical studies have been devoted to his work, and although his work is held in high esteem all over the world, we know relatively little of his working process. More particularly, we know very little on Rodin’s stance towards the two leading casting techniques of his time, the lost wax method and the so-called sand mould casting. Of the more than seventy copies of the *Thinker*, that are acknowledged as having been cast under the direct surveillance of Rodin or by his authorised beneficiary, the French State in the form of the Rodin Museum, almost all are sand mould castings, only three were cast in the lost wax method. Since the Singer Laren

copy of the *Thinker* appears also to have been cast according to the sand mould cast procedure, I became interested in the possibilities, the history and background of this method, and in Rodin's artistic, technological and practical preferences.

Research methodology

The research prior to the treatment of the Laren *Thinker* and the subsequent exhibition, organised after completion of the treatment, raised a number of questions.[2] Some of these questions relate to art technological aspects of the bronze and concern the casting technique employed to produce the Laren bronze. The Laren *Thinker* is a hollow bronze cast in one piece and literature describing the casting techniques of Rodin bronzes, mention the fact that the Rodin bronzes of this period were cast using sand moulds.[3] For the average conservator this is somewhat surprising because the casting in sand moulds is nowadays not associated with intricately shaped, hollow bronze sculpture. A modern foundry would choose invariably lost wax casting as the preferred method to cast a detailed figural hollow bronze. As a conservator with an interest in the art-technological aspects of an object, I tried to comprehend the method of using sand as mould material to produce the Laren *Thinker*.

I therefore consulted technical literature and contacted several colleagues with knowledge of foundry techniques. Although some questions regarding the technique were answered, many remained. For most of the technical features I observed on the exterior and interior of the bronze, the existing literature gave no proper explanation. Because sand mould cast bronzes are almost absent in the art-technological literature, one has to fall back on manuals such as Rama's *Le bronze d'art et ses techniques.*[4] Although extremely useful as reference work, this instruction manual does not give an historical account and is of limited use in explaining characteristics found on historical sand mould cast bronzes. The casting in sand moulds for the production of works of art, turned out to be a poorly researched area, technically as well as historically. Very little was known regarding the history of use of this technique and its development.

When considering the history of Western bronze sculpture casting, the nineteenth century and first half of the twentieth century are rather unique. While lost wax casting was the preferred method in Renaissance and Baroque times, the sculptor working roughly between 1810-1960 in Western Europe often opted for an alternative method: casting using sand moulds.[5] Except

[2] The exhibition centred on the newly restored *Thinker* in Laren [28.01.2011-22.05.2011] brought together some early casts of the *Thinker* and gave an unique opportunity for comparison, see Tilanus, P., et al. *Rodin: De Denker*. Thoth, 2011.
[3] Wasserman, J.L. *Metamorphoses in 19th-century sculpture*: exhibition, November 19, 1975-January 7, 1976, Fogg Art Museum, Harvard University (1975): 145-179; Le Normand-Romain, A. *The Bronzes of Rodin*: *Catalogue of Works in the Musée Rodin*. Musée Rodin (2007): 19.
[4] Rama, J. P. *Le bronze d'art et ses techniques*. Éditions H. Vial, 1988.
[5] Ekserdjian, D. (ed.). *Bronze*, Royal Academy of Arts, 2012.

for Italy, sand mould casting became the method of choice to cast bronze sculpture in France, Germany, the Low Countries and the United Kingdom.[6]
Current literature tells us that the casting of complex sculpture in sand moulds was a relatively late development originating at the end of the eighteenth century in France.[7] During the first quarter of the nineteenth century, sand mould casting replaced lost wax casting as the preferred method to reproduce bronze sculpture in Western Europe. By the end of the nineteenth century the sand mould casting technique was so well developed that founders were capable of casting complex figurative bronze sculpture, such as Rodin's *Thinker*, in one piece. Virtually nothing has been written on the casting technology of Rodin bronzes and no specialist study has been carried out researching sand mould cast bronzes in general and Rodin bronzes in particular. In those publications that look at the role of sand and lost wax casting in the nineteenth century, for example Lebon, the focus is on the historical aspects, not on the technological aspects.[8]

This shift in the preference from lost wax towards sand mould casting during the nineteenth century is of great importance for the development of bronze casting and essential to fully understand nineteenth and early twentieth century bronze sculpture. However, our understanding of this technological shift is very limited and increasing our knowledge of the said shift is one of the main aims of this thesis.

In order to be able to answer this question of the change in preference from lost wax to sand mould casting, a thorough understanding of the technological development of casting in sand moulds as well as lost wax casting is required. Because sand mould casting was the alternative for lost wax casting, both methods were often competing with each other.[9] Sand mould casting can therefore not be researched in isolation and the developments in nineteenth century lost wax casting also need to be looked at.

The technical study of historical bronzes has concentrated up till now mainly on Renaissance and Baroque bronzes. Important studies have shed more light on the working practices of sixteenth, seventeenth and eighteenth-century artists and founders.[10] The bronzes cast during these periods are almost invariably cast using the lost wax method. The nineteenth century witnesses the introduction of the casting of sculpture in sand moulds with both techniques,

---

[6] For Italy also see Shapiro, M. E. *Bronze Casting and American Sculpture 1850-1900*. University of Delaware Press (1985): 117 and sub-chapter 2.5 *Evidence for sand mould casting in nineteenth century Italy* in this thesis. The situation in other parts of Europe such as Scandinavia, Middle and Eastern Europe was probably comparable but this research has focused on Western Europe. The situation in the United States was comparable to the UK; see sub-chapter 2.6 *The casting of sculpture in Britain using piece-moulds: 1800-1900* in this thesis.

[7] Lebon, É. *Fonte au sable – Fonte A cire Perdue: Histoire d'une Rivalité*. INHA (2012): 23.

[8] Lebon 2012.

[9] For more on this, see sub-chapter 5.3.1 *Hébrard versus Rudier: lost wax versus sand* in this thesis.

[10] See for example; Stone, R. E. "Antico and the Development of Bronze Casting in Italy at the End of the Quattrocento." *Metropolitan Museum Journal*, Vol. 16 (1981): 87-116; Bewer, F. G. *A Study of the Technology of Renaissance Bronze Statuettes*, Ph.D. diss. University of London, 1996; Bassett, J. L. *The Craftsman Revealed: Adriaen de Vries, Sculptor in Bronze.* Getty Publications, 2008; Bresc-Bautier, G. et al. *Cast in Bronze: French Sculpture from Renaissance to Revolution,* Musée du Louvre Éditions, 2009; Lein, E. *Ars Aeraria; Die Kunst des Bronzegießens und die Bedeutung von Bronze in der florentinischen Renaissance*. Verlag Philipp von Zabern, 2004.

lost wax and sand mould casting, used concurrently. Foundry practices during the nineteenth century have received relatively little scholarly attention, although in recent years, especially in sculptor's monographs, papers with technical aspects have appeared, some detailing artist specific casting techniques.[11] In order to place the sand mould casting technique within the wider context of foundry technology, a full narrative of the historical development of sand mould casting is required. Literature giving a thorough chronological historical overview of the use of sand moulds for casting, is non-existent and when sand mould casting is mentioned this is done very superficially and brief. The only author known to have written on the historical development of casting in general, Cyril Stanley Smith, writing in 1981, gives a very brief and incomplete historical outline of the early history of casting.[12] Susan La Niece has given a short historical development of sand mould casting in the Islamic world, which falls outside the scope of this thesis.[13] However, many questions still remain concerning the origins of sand mould casting in Europe. For example, it is not clear where, when and why the casting in sand moulds in Europe first started. Therefore, in chapter one I will chart the technical development of casting in sand moulds up till the end of the eighteenth century, in order to make the reader fully understand the conditions which led to the casting of sculpture in sand moulds around 1800.

Scholars of sculptural bronzes have always wondered whether sand mould cast bronzes are by definition from the nineteenth century and later, or whether there are earlier examples of sand mould cast bronzes. This is particularly important for the dating and authentication of the many casts, after-casts and copies of Renaissance and Baroque bronzes produced in the nineteenth century. Current literature does not give conclusive evidence for the use of sand moulding of complex sculpture before 1800. This is one of the reasons why this research tries to establish earlier use of this technique.
The *Thinker*, as the main focus of this research, can be seen as exemplary for Rodin's bronze sculptures. Produced from the early part of his career up to half a century after his death, the *Thinker* was, and still is, one of Rodin's most iconic and most popular sculptures. Available in three sizes and reproduced in the original size (71,5 cm)[14] more than fifty times and in the enlarged size more than twenty times by seven different foundries, cast in both sand moulds

[11] Excellent work has been carried out by Ann Boulton on Matisse and Barye; Boulton, A. "The making of Matisse's bronzes." *Matisse Painter as Sculptor*. D. Kosinski (ed.) Baltimore Museum of Art (2007): 73-97 & Boulton, A. "The art bronze foundry of Antoine-Louis Barye." *Untamed – The art of Antoine-Louis-Barye*. Johnston, W. R., et al. The Walters art museum (2006): 66-72. On Degas bronzes by Anne Pingeot, Arthur Beale, Daphne Barbour and Shelley Sturman in Czestochowski, J. S., and A. Pingeot. *Degas, Sculptures: Catalogue Raisonné of the Bronzes*. International Arts, 2002.
[12] Smith, C. S. "The early history of casting, molds, and the science of solidification." *A Search for Structure*, MiT Press (1981): 127-173.
[13] La Niece, S. "Sand casting in the Islamic World" *Verborgenes Wissen: Innovation und Transformation feinschmiedetechnischer Entwicklungen im diachronen Vergleich*. Armbruster, B et al.(Eds.), Tagungsbeiträge des Netzwerks Archäologisch-Historisches Metallhandwerk 1. 5.–6. Mai 2011. (2016): 263-276.
[14] Rodin would eventually produce the *Thinker* in three sizes:
1) the original size *Thinker* as used for the Gates of Hell, the so-called '*taille originale'*, with a height of approximately 71.5 cm; 2) a reduced size of ca. 37.5 cm; 3) the monumental outdoor version of circa 190 cm, the so-called '*Grand Modèle'*

as well as with the lost wax method, the *Thinker* provides us an excellent insight into the working practices of the producers of Rodin bronzes.

Rodin bronzes and in particular his *Thinkers* are particularly well suited as representative examples of late nineteenth and early twentieth century bronzes. This is because Rodin bronzes, including the *Thinkers*, have been produced over a long period, from the mid 1870s to present times, by almost all major contemporary Parisian foundries and with all, then current, bronze founding techniques. The focus of this research is the original or medium size *Thinker*, the enlarged or reduced *Thinkers* are outside the main scope of this research. The smaller, reduced *Thinkers* are not an easy group to study because of lack of sufficient documentation and provenance and thus giving often rise to authentication issues and has therefore hardly been used in this study. The enlarged monumental version is much better documented but is difficult to study technically. Because of its size and location, the owners of these large bronzes are usually not inclined to move these to allow technical study of the interior of the bronze. Of the original and enlarged *Thinker* various foundry and exhibition plaster models survive together with a wide array of documentation. However, this study does not limit itself to Rodin bronzes to establish whether the techniques used for Rodin bronzes are any different from bronzes by other sculptors. It is important to state here that the aim of this study is not to be the definitive work on nineteenth century sculpture founding. The scale of such a work is immense and would have to include a wide array of examples from many bronze producing countries during the entire nineteenth century. It is hoped by the author that the selection of examined bronzes provides a useful template for further study.

A large number of bronzes were studied for this research, in collections in Europe and the United States. The exhibition in Laren, which brought together a number of *Thinkers*, provided also ample opportunity for comparison and study of this well-known sculpture.[15] A total of four bronze casts were amongst the exhibits: two life-time casts, the first *Thinker* from 1884 from the collection of the National Galleries of Victoria in Melbourne, the second or third cast (1896) from the Musée d'Art et d'Histoire in Geneva (inv.no. 1896-0011) and two posthumous casts; the Laren *Thinker* (c. 1937) and one of the last authorised casts from 1967, lent by the Musée Rodin.[16] The bronzes from Laren, Geneva and Paris were all cast using sand moulds, a casting technique used to produce the majority of Rodin bronzes and most of the nineteenth and early twentieth century bronze sculptures.[17] Close examination of the *Thinker* from Melbourne, during the installation of the exhibition, revealed this, however, to be a lost wax casting. This was surprising, because up till then, all known *Thinkers* of this size were described in the literature as sand mould castings. Subsequent literature research into Rodin bronzes, cast during the 1880s, showed that Rodin, who never performed his own

[15] Twenty-one sculptures in bronze, plaster and stone from the collections of the Rodin Museum, Paris, Singer museum Laren, Kröller-Müller museum Otterlo and the Rijksdienst voor Cultureel Erfgoed Rijswijk.
[16] National Gallery of Victoria, Melbourne, Felton bequest inv.no. 1196-3; Singer Laren museum; inv.no. 56-1-412. The Laren *Thinker* was probably purchased in Paris during a visit of Anna Singer to the Rodin Museum in Paris in 1937, see Rijk. A. de. "*De Rodins van Anna en William Singer"* Tilanus et al. (2011): 73; Rodin Museum, Paris, inv.no. S. 788
[17] Le Normand-Romain 2007, 19 & Young, M. L., et al. "Matisse to Picasso: a compositional study of modern bronze sculptures." *Analytical and Bioanalytical Chemistry* 395 (2009): 171-184.

castings, occasionally commissioned lost wax foundries between 1882 and 1886.[18] The Melbourne *Thinker* from 1884 fits very well into this group and we know that Rodin expresses, also in 1884, his preference for lost wax casting when he writes, in preparation for the execution of his *Gates of Hell* in bronze, to a government minister: "Lost wax casting, the only process which can render my sculpture."[19] And in 1889 Bartlett writes: "… Rodin, like all good sculptors, prefers bronze reproductions of his models, and by the wax process. In this way his work is not changed by any intermediate hand in its transformation from one material to another."[20]

Although Vassalo states that Rodin never definitely decided for one or the other casting technique, [21] it is significant that of the more than 1500 authorised life-time casts, only a small fraction, around 60, was cast using the lost wax technique and no Rodin bronze was lost wax cast from 1913 onwards.[22] Why then did Rodin choose to have the majority of his bronzes cast using sand moulds instead of lost wax casting? This is one of the questions I want to address in the current dissertation.

The recent discovery that the first *Thinker* from Melbourne was cast using the lost wax method, raised a question about the identity of the founder of this particular copy. The bronze is not marked by the foundry and no documentation has come to light connecting the bronze to a specific foundry. Up till now it is a mystery who produced the first of one of Rodin's most iconic bronzes. The material aspects of the sculpture, such as chemical analysis and casting features, can perhaps provide enough information to support an attribution to a foundry. I will address this issue in Chapter 5

Several other questions, regarding the technique of sand mould casting, arose during the treatment of the Laren *Thinker* and the current research. Although Rodin's work has received a great deal of attention from art historians, the art technological aspects of his sculptures have received, in comparison, very little attention. This makes it difficult for researchers, looking in detail at his sculptures, to interpret technical features correctly. While some of Rodin's studio practises are known from contemporary observers, very little is known of the workshop practises of the foundries employed by Rodin to cast his bronzes.

The use of complex cores and the resulting evidence in the form of core irons and flashing could not be answered by consultation of existing literature on Rodin and other nineteenth and early twentieth century bronzes. Sanders covers to a certain extent the making of Rodin bronzes, without going into too much technical detail, in the exhibition catalogue *Metamorphoses in nineteenth-century sculpture* and Antoinette Le Normand-Romain devotes only one page to the process of casting in her catalogue of the bronzes at the Rodin Museum

[18] Le Normand-Romain 2007, 730.
[19] "Le travail de la fonte à cire perdue, le seul qui pourra rendre ma sculpture."; Rodin writing to a government minister on 11 December 1884, see Le Normand-Romain 2007, 21. All quotes in the main text of this thesis are in English with the original text in the footnote.
[20] Bartlett writing in 1889 on Rodin, see Elsen 1965, 84.
[21] "Rodin n'ait jamais tranché definitivement pour l'une ou l'autre.", see Vassalo 1992, 61.
[22] Vassalo 1992, *Production des bronzes par fondeur*. np

in Paris.[23] A more general work such as Michael Edward Shapiro's *Bronze Casting and American Sculpture 1850-1900* describes casting in sand moulds more detailed but still not enough to provide the reader a full understanding of this technique and therefore enable to explain certain features visible on bronzes.[24] For a more detailed, step by step account, one has to consult more technical works such as foundry manuals. Rama for example, provides the reader with detailed information on various casting methods including casting in sand moulds.[25] The problem with Rama's publication is that it details general foundry methods practised in the 1980s and not during the last quarter of the nineteenth century. No moulding or casting of Rodin bronzes is illustrated or discussed in Rama's book. To establish whether the foundry practices of the 1980s in general and for Rodin bronzes in particular, are comparable with practices a century earlier one has to study more primary source material such as nineteenth and early twentieth century foundry manuals.

Very little is known on historic working practises of foundries using sand moulding and more specifically the piece-moulding used for the production of sculpture. There is an urgent need to understand the origins and early developments of sand mould casting in general and piece-moulding in particular. This lack of published information on historic sand mould casting and sand mould cast bronzes makes it difficult for conservators and curators to fully understand these bronzes. Foundries are known for save guarding their working methods and this thesis tries to elucidate these through study of contemporary accounts such as manuals, newspaper articles and other contemporary observations. Especially the technical details of the casting of Rodin bronzes, the *Thinkers* in particular, will be researched.

The Laren Thinker and the use of 3D technology

During the research, in preparation for the exhibition, the question of the production date of the Laren *Thinker* arose. Documentation in the museum archive suggests the Laren *Thinker* was acquired by Anna Singer around 1937. Since the bronze was bought after Rodin's death and detailed information regarding the purchase has not come to the surface yet, the question remains whether the Laren *Thinker* could be an earlier, perhaps even a life-time, cast. This issue was of course also of importance for the final decision on treatment options of the sculpture after its retrieval. In order to answer this question a more detailed picture regarding the casting sequence of Rodin's *Thinkers* and the place of the Singer Laren *Thinker* within this series is required.

When the Laren *Thinker* was vandalised in 2007, it was deemed by many to be irretrievably damaged. The extent of the damage was such that only heavy interventive restoration could restore the sculpture to a, for the museum acceptable, appearance. Because traditional bronze restoration techniques were considered too damaging and irreversible, a new innovative approach was required. Therefore, the use of 3D scanning and 3D printing was explored. In 2007, the use of 3D techniques in conservation/restoration was a largely unexplored field and

[23] Sanders, P. "Auguste Rodin", in Wasserman 1975, 145-179; Le Normand-Romain 2007, 63.
[24] Shapiro 1985, 16-23.
[25] Rama 1988.

if used, it was mainly for documentation purposes.[26] The heavily damaged Laren *Thinker* required a far more elaborate use of these 3D techniques to make up missing parts that could be placed in the sculpture. This was not attempted before and the question arose whether these innovative 3D techniques were suitable to apply directly in sculpture conservation/ restoration?

During my research, 3D scans were produced of the sand mould cast Laren *Thinker*, the lost wax cast Melbourne *Thinker* and a plaster foundry model of the *Thinker* from the Rodin Museum in Paris. In collaboration with the Metropolitan Museum of Art in New York, a comparison study was set-up to compare the 3D scans of the various *Thinkers* to see whether differences could be observed in shape and dimensions between the sculptures. Especially interesting would be to see whether differences could be observed between the lost wax casting and sand mould casting, this could be potentially very interesting for authentication purposes.[27]

The vandalisation of the Laren bronze initiated a public debate on the restoration. Questions were raised about the need and justification of this. In the final chapter, I will look at this discussion from the point of view as a technical art-historian and a conservator. I will also reflect on the implications and usefulness of innovative techniques such as 3D imaging and printing in sculpture conservation.

The central aims of this thesis

The main focus of this thesis is to make a significant contribution to our knowledge of the art-technological aspects of nineteenth and early twentieth century bronze sculpture, in relation to the oeuvre of Rodin and more particularly his *Thinkers*. Research into the art-technological aspects of bronze sculpture founding started in the early 1980s when Richard Stone published in 1981 the first serious study into Italian Renaissance bronze casting technology. For this study, he used mainly x-radiography to study the bronze statuettes.[28] Fifteen years later Francesca Bewer completed her PhD, also on Renaissance bronze casting.[29] In this study she used, in addition to X-radiography, XRF surface analysis to determine the alloy composition of the statuettes she examined for her research. In the past decade, an increasing number of art-technological studies on bronzes have been published. In her 2008 monograph on the casting technique of the Renaissance artist Adriaen de Vries, Jane Bassett used X-ray and XRF techniques and additionally looked at core material.[30] Robert van Langh's doctoral work on Renaissance bronzes from 2012, introduced neutron imaging techniques as a research tool

[26] De Roos, H. "The Digital Sculpture Project: Applying 3D Scanning Techniques for the Morphological Comparison of Sculpture." *Linköping electronic articles in computer and information science*, Vol. 9 (2004) no.2. <http://www.ep.liu.se/ea/cis/2004/002/cis04002.pdf> [accessed 22-6-2018]

[27] The traditional way of identifying whether a bronze sculpture is cast using the lost wax or sand mould casting technique, is to look at the casting features which can be observed on the interior of a bronze. For more on this, see sub-chapter 6.7 *A comparison between Thinkers using 3D imaging* in this thesis.

[28] Stone 1981.

[29] Bewer 1996.

[30] Bassett 2008.

for bronzes.[31] Manon Castelle's thesis on French large Renaissance and Baroque bronzes used a wide variety of analytical techniques including X-ray, core analysis using PIXE and ICP-AES.[32] ICP techniques have been used for bronze alloy determination for several years now.[33] What most of these above mentioned publications have in common is a strong emphasis on material analysis. Although foundry techniques are discussed, invariably lost wax casting, the intricacies of the actual manual procedure are rarely described in these studies.

This study tries to enhance our knowledge in two specific, relating, areas:

- development of the introduction and use of sand moulds in early modern Europe, leading up to the use of sand mould for the production of large sculpture
- detailed practical knowledge of historical sand moulding and casting in general and more specific to the oeuvre of Rodin and his *Thinkers*

The precise manual execution of historic art-technological processes is often poorly understood and described. A possible explanation for this can be the fact that textual and pictorial source material from before the nineteenth century is often of a very limited nature. Combined with the fact that very few academics, researching craft processes, have a background as professional practitioner makes that research in art and craft techniques is often focused on material analysis and/or textual source analysis, and rarely on the intricacies of the actual art/craft-technique.

Structure of the dissertation

Although the treatment of the Laren *Thinker* initiated the later art-technological research into sand mould casting, I have opted to start the thesis with the technical development of the use of sand as a moulding material giving the thesis a historical chronology.

The thesis starts with an overview of the various types of historical casting methods. A definition of sand mould casting is formulated and the different forms of sand mould casting are briefly described (§1.2). The next paragraph (§1.3) charts chronologically the early development of the use of sand as a moulding and casting material for metal objects in Europe by examples of sand mould casting in various metalworking professions. A technical evolution is given leading up to the first use of piece-moulding, essential for the development of the casting of complex sculpture in sand moulds around 1800 (§1.3.1-1.3.3).

The emergence of sand mould casting in favour of lost wax casting is the subject of Chapter 2. Starting in France (§2.2) the new technique was soon practised also in Germany (§2.3) and other European countries such as Britain (§2.7) and even Italy (§2.4). Chapter 2 also details

[31] van Langh, R. *Technical Studies of Renaissance Bronzes*, Diss. TU Delft , Rijksmuseum, 2012. Initially published as a paper in van Langh, R., et al. "The study of bronze statuettes with the help of neutron-imaging techniques." *Analytical and bioanalytical chemistry*, 395(7) (2009): 1949-1959.
[32] Castelle, M. *Les techniques de fabrication de la grande statuaire en bronze 1540-1660 en France*, Diss. Paris Saclay, 2016.
[33] Young 2009, 171–184.

the lost wax casting of sculpture in nineteenth century Europe (§2.10) and looks at the evidence for the casting of bronze sculpture in sand piece-moulds before1800 (§2.9).

Chapter 3 brings us closer to Rodin and his *Thinker* by looking closely at his studio practice. This Chapter details the steps from modelling in clay, the making of a master model and the mould making for the production of his plaster models (§3.2-3.3.4) The role of these plaster models is also discussed, both from an art-historical and an art-technological view (§3.5-3.6)

One type of these plasters, called foundry models, are essential for the sand mould casting of Rodin bronzes. The intricacies of the use of these plasters in the foundry process is covered in Chapter 4 together with a detailed description of the entire piece-moulding process in sand. The research in the previous Chapters was largely based on historical textual and pictorial source material. In this Chapter, the first material analysis is presented when moulding sand is closely examined. Paragraph (§4.2.2-4.2.2.5) presents research into the properties of moulding sand and the effect of heat on this sand (§4.2.2.6). Additionally, this Chapter also presents compositional data of the alloys used for Rodin bronzes (§4.2.8). Chapter 4 concludes with the final steps in the production of bronzes, the finishing and patination (§4.2.10-4.4).

Chapter 5 uses evidence gathered in the previous chapters to interpret technical features observed during examination of Rodin bronzes. These features are used to propose a chronological sequence and to make attributions. Additional data is presented on alloy composition (§5.3.6) and a new method is proposed, using 3D scanning, to differentiate between a sand mould cast bronze and a lost wax cast bronze (§5.4) This chapter also tries to understand Rodin's motivation for choosing a specific foundry technique (§5.2-5.3)

The concluding Chapter 6 presents the case of the vandalised Laren *Thinker*. Firstly, the discussion regarding possible treatment (§6.2.2) and the decision-making process are covered (§6.3.1), followed by its characterization, research into treatment options and the subsequent treatment of the bronze (§6.3.2-6.3.5.3) The innovative use of 3D scanning and printing in this treatment are detailed and evaluated in paragraph §6.4. The concluding paragraph §6.5 of this chapter and thesis discusses the way the treatment was communicated to the conservation field and public.