Congresso Brasileiro de Engenharia e Ciência dos Materiais
06 a 10 de Novembro de 2022 | Águas de Lindóia – SP – Brasil

STUDY OF USIBOR® 22MnB5 STEEL FOR HOT STAMPING – A BIBLIOMETRIC STUDY

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ABSTRACT

In the automobile industry, the increasingly sought after goal is to produce vehicles that are economically advantageous and that emit less pollutants into the atmosphere. A suitable choice to achieve these requirements is the use of the hot stamping process, which consists of austenitizing a blank (plate or flat disc that has undergone the cutting process on the coil and which will be formed through the stamping process) and later forming and cooling rapidly simultaneously, so that a complete martensitic transformation occurs. This process is successful in the manufacture of lighter parts with high tensile and impact strength, providing safety to vehicles. After the sheet cutting process, the material is known as a blank and after passing through forming and quenching it is recognized as the final part. A material widely used in the hot stamping process is the high strength low alloy (HSLA) steel known as Usibor® 22MnB5, which has a large content of manganese in its composition, which in turn is an element that does not have much influence on the strength of the material after quenching, but increases the hardenability of the steel by delaying the transformation of austenite. In addition, Usibor® 22MnB5 steel has a martensitic transformation start temperature of 410°C, a critical cooling rate for the martensitic transformation of 27°C/s, an initial yield stress of 457 MPa and 1010 MPa after being hot stamped, and an initial tensile strength of 608 MPa and 1478 MPa after being hot stamped. This steel has an Al-Si protective coating layer, which prevents the blank from oxidizing at high temperatures. Even with several published articles and studies carried out on 22MnB5 steel, some concepts are still unknown. Thus, in this work, a bibliographic review will be carried out to support the evaluations that will be performed to verify the effect of the previous cold deformation and the simultaneous deformation and quenching on the hardenability of blank steel. In addition, a bibliometric analysis will be performed concerning the bibliographic coupling by publications and the co-occurrence of keywords in articles already published, in order to understand the relevance of the subject.

Keywords: *Hot stamping, 22MnB5, phase transformation, blank, Al-Si coating.*

INTRODUCTION

In recent decades, the continuous development of sheet metal technology has provided greater savings and efficiency in the manufacture and use of durable consumer goods. When it comes to the automobile industry, such improvements have a great impact, since it is a broad market, in which consumers are increasingly looking for vehicles with higher performance, lower cost and conservation of the environment[1]. Environmental regulations determine limitations for the emission of greenhouse gasses, vehicle safety and energy efficiency of vehicles. Thus, the aim is to produce sheets with smaller thicknesses and good mechanical resistance, so that vehicles do not have their performance affected (in collision situations, for example), but are lighter, reducing fuel consumption and the emission of polluting gasses[2]. The automobile industry is increasingly using new materials to improve performance, reduce weight and improve passive safety in automobiles, which promotes the use of new structural components: high-strength low-alloy (HSLA) steels. Among the class of HSLA steels, there are martensitic steels and low carbon steels microalloyed with boron. Boron steel is processed by hot stamping, a process that causes an increase in the mechanical strength of the steel after forming, as well as a decrease in its elastic recovery and the strength required for stamping. Compared with high strength cold stamped steels, this stamping process can produce structural components with more complex geometries, greater elongation, less spring effect and higher strength requirements[1]. Usibor® 22MnB5 steel is widely used in the automotive industry, presenting an initial structure composed of ferrite and pearlite, which is austenitized for hot forming, and a totally martensitic structure when quenched and quickly cooled[4]. This steel is one of the most used in hot stamping processes and can achieve mechanical strength values above 1400 MPa[3]. In order to understand the relevance of studies and research on Usibor® 22MnB5 steel, a literature review and bibliometric analysis were performed.

MATERIALS AND METHODS

The bibliographic review and bibliometric analysis contained in this work were carried out based on a search on the Web of Science platform, carried out on August 3, 2022. Initially, the keywords related to 22MnB5 steel and the process of hot stamping were searched. The search was refined based on the research areas of engineering, materials, mechanics and metallurgy, and on languages, considering only publications in Portuguese and English. Following the refinement of the data, the 411 resulting works were exported and the number of publications analyzed over the years. After this initial analysis, the database was taken to the bibliometrics software VOSviewer to be processed, in order to obtain the maps to perform the bibliometric analysis, and consequently to understand the trend of research on blank material for hot stamping and view the characteristics of publications on the subject. In VOSviewer, the co-occurrence map of the keywords related to blank steel and the hot stamping process was initially built. To perform this step, it was necessary to filter some words using the VOSviewer's 'thesaurus file' command, so that common terms would not be repeated, making the analysis more accurate. Keywords that were used at least 10 times were considered in this analysis. Then, the bibliographic coupling map by publications was built to analyze the number of citations of a given publication, and consequently filter the most relevant publications. At this stage, in order to select the 20 most relevant publications, only publications that were cited at least 60 times were considered.

RESULTS AND DISCUSSION

Figure 1 shows the variation in the number of publications on hot stamping and the material used for the blank, 22MnB5 steel, over the years. It is possible to notice that this is a relatively new subject, since the first works were published in 2005. From 2010 onwards there was an increase in the number of publications, reaching a maximum in 2017 with 52 publications. Currently, in the eighth month of 2022, there were only 13 publications, that is, less than half the number of publications of the last 4 years, which in turn was above 30.

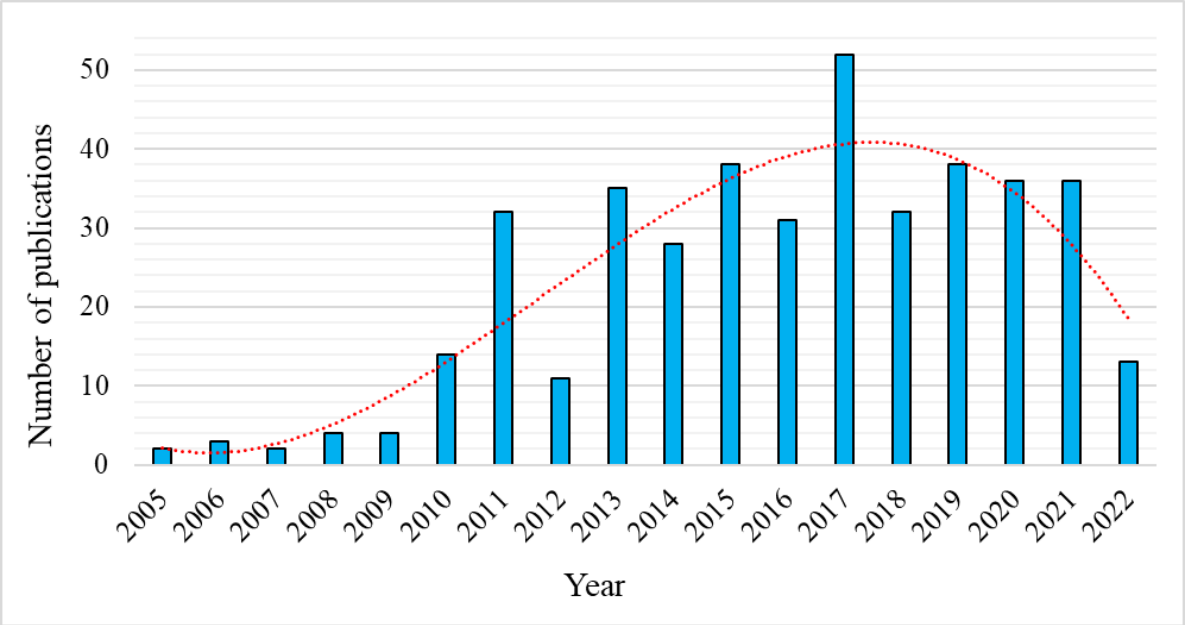

Figure 1: Variation in the number of publications related to 22MnB5 steel and hot stamping over the years.

Co-occurrences between pairs of words can be analyzed to determine the strength of the association between these words. This analysis can be used to create indexes that represent the state of a field of knowledge, and can help in the development of tools for indexing and retrieving information. In addition, this analysis can be used to prepare scientific articles and can even help to develop logical systems for indexing processing and information retrieval[7]. Thus, the co-occurrence map of the keywords related to blank steel for hot stamping is presented in Figure 2, in the form of a network visualization, to show how the main keywords used in the publications are interconnected. Initially, the database had 1114 keywords. These words were treated in such a way that similar terms were replaced by just one term. After processing the data, 548 keywords remained. These underwent a refinement so that the minimum number of occurrences of each keyword was 10. Thus, 30 keywords remained, but some had no relevance to the project from the study of blank material for hot stamping. Finally, 26 keywords remained for the analysis. As shown in Figure 2, it is possible to notice the presence of 3 clusters distinguished by the colors red, yellow and blue, such that each cluster represents how certain words are often linked with others. Note that the words in the red cluster represent the mechanical properties linked to the blank material, while the words in the yellow cluster are linked to the hot stamping process and the words in the blue cluster are linked to their phases and phase transformations. It is also noted that the keyword related to the hot stamping process 'hot-stamping' was the one with the highest frequency in the analyzed publications, with 279 occurrences and a connection strength of 846. The keyword related to the material of the blank '22MnB5' came in second place, with 227 occurrences and a bond strength of 783. Thus, blank

material for the hot stamping process is a very relevant topic, as keywords related to this topic are present in most publications on the subject.

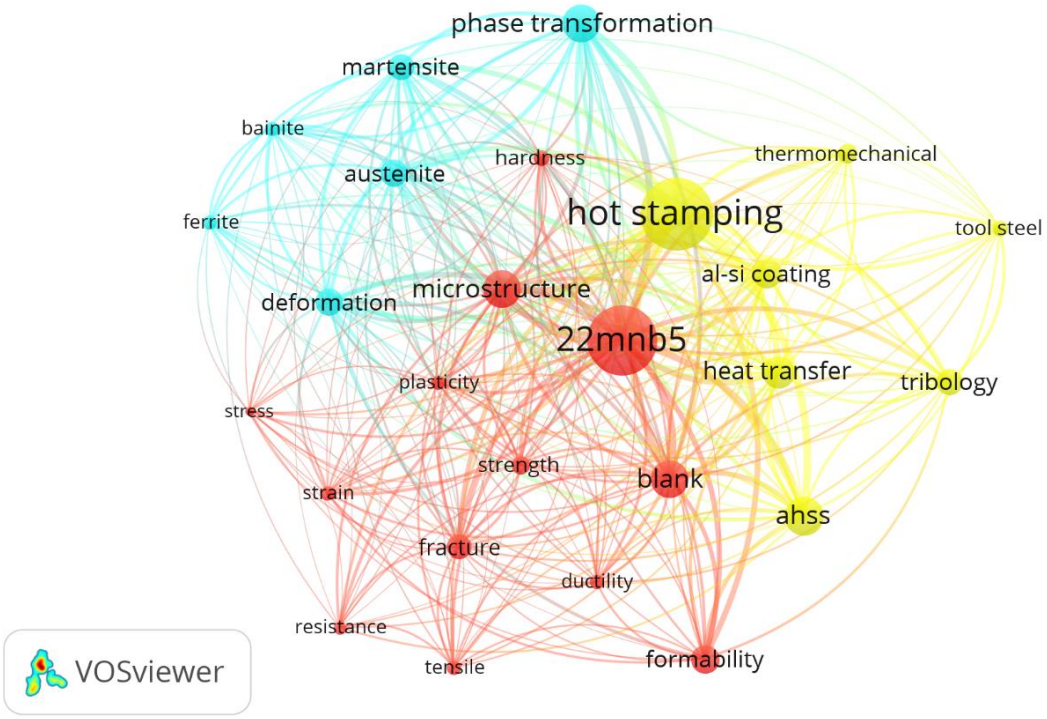

Figure 2: Co-occurrence map of keywords related to blank steel for hot stamping in the network view.

Bibliographic coupling is a method developed in the 1960s and is capable of measuring the relationship between two publications based on the number of common references cited by each publication[5]. The intensity of coupling depends on the number of references that two publications have in common, so the greater the number of references in common, the greater the strength of connection between them. Thus, the bibliographic coupling allows the study of the development of research lines, making it possible to identify the most relevant research centers and publications in a given domain[6]. Bibliographic coupling by publications related to blank material for hot stamping is presented in Figure 3 through an overlap view of the number of citations by year of publication. The minimum number of citations per publication considered was 60 citations. Thus, the article by Karbasian and Tekkaya published in 2010 stood out, since it has 1040 citations, providing an overview of the hot stamping process[8]. Another very relevant publication was the article by Merklein and Lechler published in 2006, with 260 citations, bringing results from a study of thermomechanical properties for hot stamping steels[9]. The publication by Turetta et al. in 2006, ranked third, with 179 citations, included a study related to the formability of 22MnB5 steel for hot stamping[10]. Other publications studied[11-27] have less than 150 citations over the years, and cover from basic concepts related to the hot stamping process to studies of the mechanical, tribological and thermal behavior of the blank material, Usibor® 22MnB5 steel. Even so, from these analyzed publications, no studies were found on the prior deformation of the material for hot stamping.

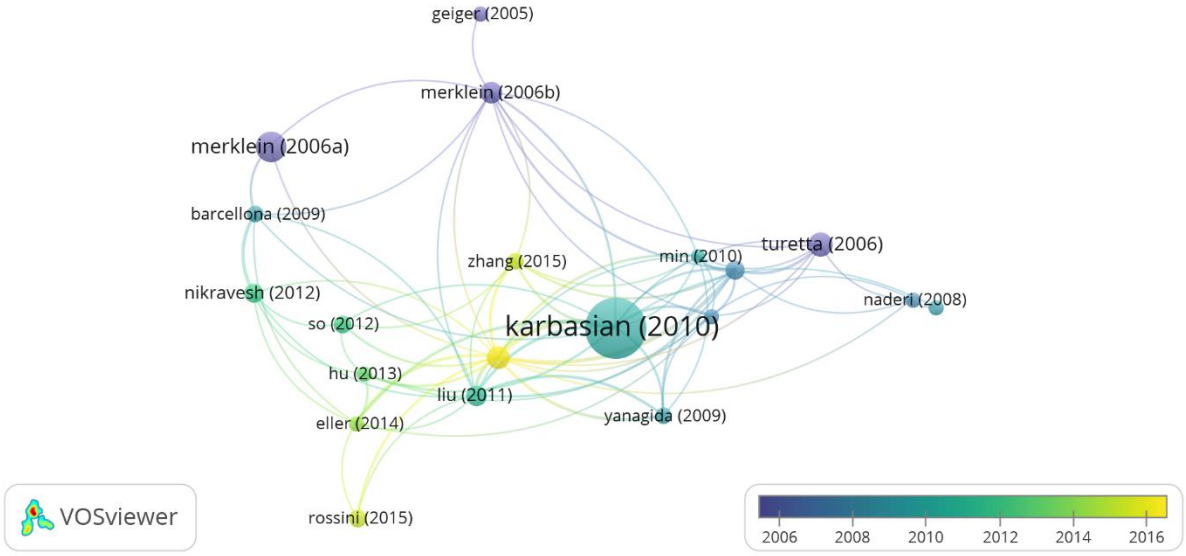

Figure 3: Bibliographic coupling map of the most referenced publications related to blank materials for hot stamping.

CONCLUSIONS

With this literature review, it was possible to understand the concepts related to the hot stamping process as well as the characteristics of the alloy most commonly used as blank, Usibor® 22MnB5 steel. This literature review will serve as a basis for further studies carried out with this steel. The topics presenting the terms blank materials and hot stamping appeared in 411 publications since 2005 according to research on the Web of Science platform. Although the subject has been extensively studied, further investigations still need to be done, such as the study of cold forming and the behavior of the hardenability of this steel when heated, formed and cooled simultaneously. The bibliometric analysis of the bibliographic coupling by publications showed that despite the topic being relatively new, there are thousands of citations, mainly regarding the article published in 2010 by Karbasian and Tekkaya. With the nationalization of the hot stamping process, it is expected that the number of publications and citations from Brazil tend to grow. The co-occurrence analysis showed that 22MnB5 steel (also known as Usibor® 1500 or PHS) was used as a keyword more than 200 times, being related to mechanical properties, phase transformations, microstructure characteristics and the process of hot stamping.

AKNOWLEDGEMENTS

The authors would like to thank the Brazilian research funding agency FUNDEP (Research Development Foundation - Project 27194*27 - Route 2030: Mobility & Logistic for the Future of Brazil, Segment IV: Most Competitive Brazilian Tools) for providing financial support for this study. The authors are also indebted to the School of Mechanical Engineering at the University of Campinas for the practical support very kindly provided.

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