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FAILURE OF THREADED JOINTS: RESULTS FROM A SURVEY ON ITALIAN COMPANIES

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ABSTRACT
Threaded joints play an important role in the definition of the reliability and safety performance of any industrial product: from earthmoving machinery to orthopaedic prostheses, from aircraft to machine tools. This joining methodology is, nonetheless, highly sensitive to several design, manufacturing and control parameters: if only one link of this chain fails, the entire system may come to unexpected failure, sometimes with severe consequences. On the one hand, the literature encompasses several review studies that analyse the main root causes of failure: these studies are necessarily focused on failures documented in the scientific literature. On the other hand, it is rather difficult to find adequately organized field-data that can help the scientific community to orient the research towards the most impelling industrial needs. Moreover, the few data available is almost entirely gathered from the automotive and aerospace sectors and dating back to the nineties of the last century and the early two-thousands. This research is based on an anonymous survey that has been submitted to Italian industries or to Italian facilities of multinational corporations, operating in several fields (automotive, earthmoving, machine tools, oil & gas and many others). The survey aimed at assessing the most frequent root causes of failure, whether the failure of the fastening system involved subsequent failure or not, whether the failures were mainly recorded upon assembly or quality control or during service life of the goods, the materials of the fasteners and/or components more prone to failure. The results have been analysed by means of statistical methods to clarify the effectiveness of each of the analysed variables. Among the most prominent findings: (i) the relative abundance of vibrational induced failures (loosening); (ii) the high frequency of assembly-related issues, mostly due to the lack of knowledge of the actual friction coefficients upon assembly; (iii) the non-negligible amount of failures related to an inexact knowledge of the actual operational loads.

KEYWORDS
Bolted Connections, Failure, Fatigue, Vibration.

INTRODUCTION
Failures in threaded fasteners can result in significant damage to machinery, with the potential for catastrophic consequences, including personal injuries and financial losses. Over the years, several reported failures have been traced back to threaded fasteners. For instance, Porsche had to recall 785 911 GT3 cars due to engine bolts loosening, which caused oil to leak into the exhaust and ignite, leading to fires. Similarly, General Motors recalled 8.4 million cars in 2014 due to issues related to faulty fasteners [1]. More recently, Tesla Motors identified a problem in the steering system of its X series cars, prompting a recall of over 3,000 vehicles. The issue was traced to bolts that corroded in highly corrosive environments, such as areas where salt is used to de-ice roads [2]. These examples highlight how seemingly small issues with bolts can lead to significant financial and human costs, including potential road accidents. The impact of bolt failures extends beyond the automotive industry. For instance, in the Gulf of Mexico, a failure of bolts in a lower marine riser package caused a leakage, leading to the replacement of several thousand bolts and causing operational disruptions [3]. The failure was attributed to hydrogen-induced stress corrosion cracking (HISCC), a result of inadequate coating processes. Such incidents emphasize the need for careful attention to the various types of fastener failures and the development of comprehensive frameworks to address them. This could lead to updates in bolt codes, standards, and design procedures aimed at minimizing losses. Threaded fasteners can

fail in various ways: for example, preload loss, caused by various types of loading on fasteners, can result in loosening of joints, which can accelerate failure. Other factors, such as improper design parameters or unsuitable material processing can also lead to failure [4]. Despite extensive experimental and theoretical studies carried out on fasteners, these seldom included studies aimed to clarify the recurrent failure modes, to orient the research effort towards the actual industrial needs. As a matter of fact, similar studies, when available, mostly date back from the 1980's through the early 2010's [5, 6]. The aim of this study is to fill the gap between the available literature and the need to clarify which key issues are still to be tackled in order to increase the reliability of fasteners throughout the industry.

MATERIALS AND METHODS

The present study has been developed by inviting approximately one hundred potential respondents, whose typical identikit is that of a technical department manager, R&D manager, senior design engineer or quality engineer, belonging to several industrial fields. The final figure of effective respondents settled upon 38 independent subjects, reflecting the vast majority of the involved industrial sectors. In order to allow the participation of the highest possible number of subjects, the questionnaire was conceived in order to be anonymous and the data were after-treated in order not to make it possible to track back the origin or organizational details of the respondent.

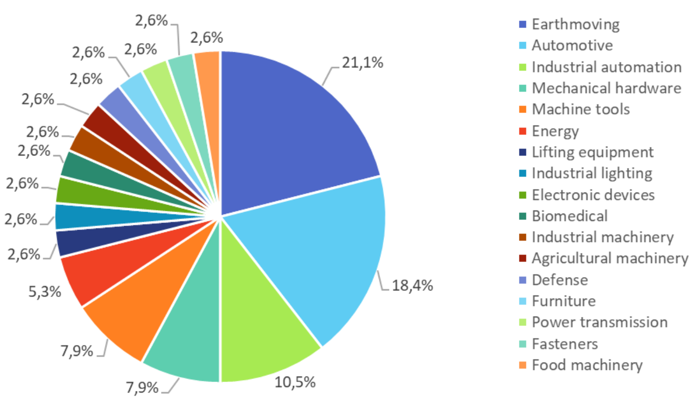

FIGURE 1: INDUSTRIAL SECTORS OF THE RESPONDENTS

As shown in Fig. 1, several industrial sectors are represented in the group of 38 final respondents to the survey. About half of the respondents, however, belonged to the earthmoving (21.1%), automotive (18.4%) and industrial automation (10.5%) sectors combined, thus making the conclusions drawn more relevant to these sectors than others. Looking at Fig. 2 and Fig. 3, it is possible to understand how the involved organizations manage the design and characterization of threaded connections. In particular, Fig. 2 refers to the company division (or external supplier) which is in charge for the design of threaded joints, whereas Fig. 3 summarizes which entity is in charge for the characterization of the hardware involved in threaded joints. Attentive examination of both these figures suggests that the

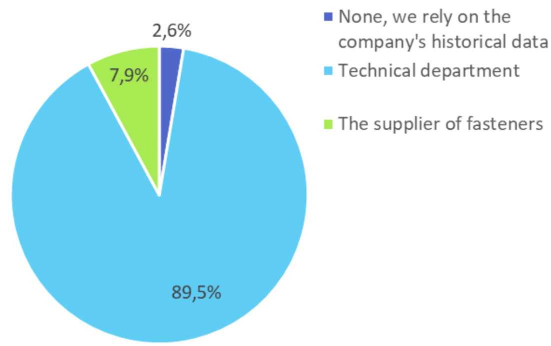

FIGURE 2: WHICH DIVISION OR SUPPLIER IS IN CHARGE FOR THE DESIGN OF THREADED JOINTS

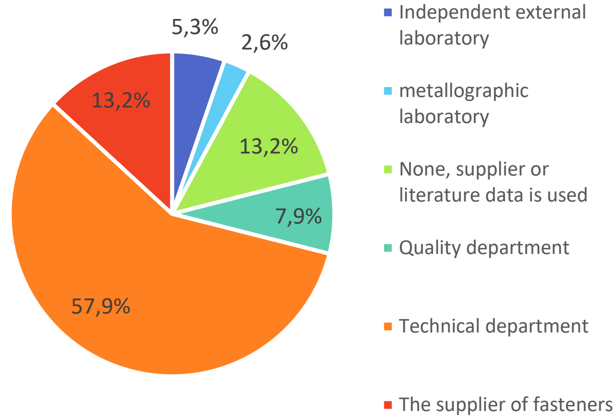

FIGURE 3: WHICH DIVISION OR SUPPLIER IS IN CHARGE FOR THE CHARACTERIZATION OF THREADED JOINTS

target of the questionnaire is well chosen, since the most part of both the design and characterization phases firmly lie in the hands of the technical department or quality department of the interviewed companies. After the organization-related initial section of the questionnaire, the respondents were asked to provide an estimate of the frequency of failures that, based on their experience, could be traced back to joints as a whole and, in a second phase, to threaded connections only. In the same section of the questionnaire, the focus of investigation has been posed on the likelihood of subsequent failures stemming from threaded joints failure and on the product lifecycle phase at which the issues were detected. In the following section of the questionnaire, the questions aimed at shedding light on the root causes of typical failure modes (e.g. overload at tightening, service fatigue, service loosening). Some questions also dealt with the service conditions of joints that appear to fail more often than others, as well as the material involved in joints that, still based on the experience of the respondent, are more likely to fail. Lastly, the professionals interviewed were asked whether they reckon any need for improvement of the bolt number and placement on their typical joints, as well as if the company is planning any actions to improve the reliability of threaded joints in the short term. Even if a comparatively large number of specialists have been involved as respondents, the results of this study shall be read within the framework of a preliminary analysis. In detail, limitations of the study can be identified as follows: (i) narrow geographical location of the respondents (the study is only based on Italian companies or Italian branches of multinational corporations); (ii) the answers are based on the sensitivity of the interviewed subject, without any possibility for the authors to access proprietary data about failure rates, root cause analyses and the like. Lastly, since the earthmoving, automotive and industrial automation sectors combine to bring about circa 50% of the total answers to the questionnaire, some analyses have been carried out not only on the general population, but the data has been broken down to the sector level, to highlight any sector related deviations with respect to the general population.

RESULTS AND DISCUSSION

First, the questionnaire was aimed at clarifying whether mechanical joints are a reason for concern for the reliability of machinery or not. Based on the results shown in Fig. 4, it is quite clear that the general population holds the joints in general responsible for a non-negligible amount of failures (answers *Often* and *Sometimes* total a 57.9%) whereas this figure doubles in the case of the earthmoving industry (answers *Often* and *Sometimes* total a remarkable 100%). On the other hand, the automotive sector seems to be less exposed to this issue, as its relevant columns are shifted to the rightmost part of the histogram.

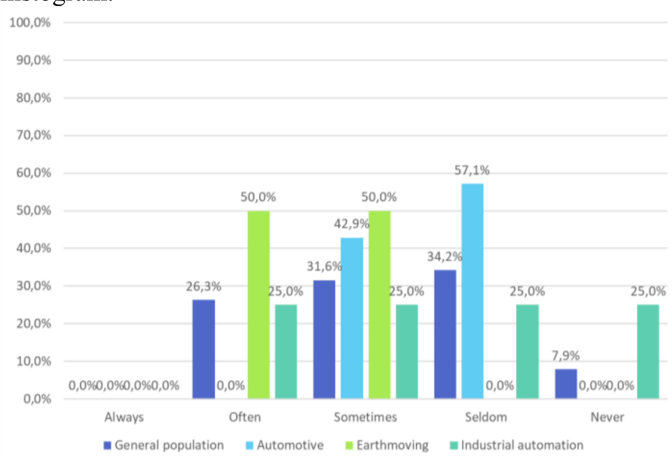

FIGURE 4: HOW OFTEN HAVE FAILURES OR NON-CONFORMITIES FOR WHICH THE ROOT CAUSE IS KNOWN OCCURRED AT JOINTS (ADHESIVE, BOLTED, WELDED, ETC.)?

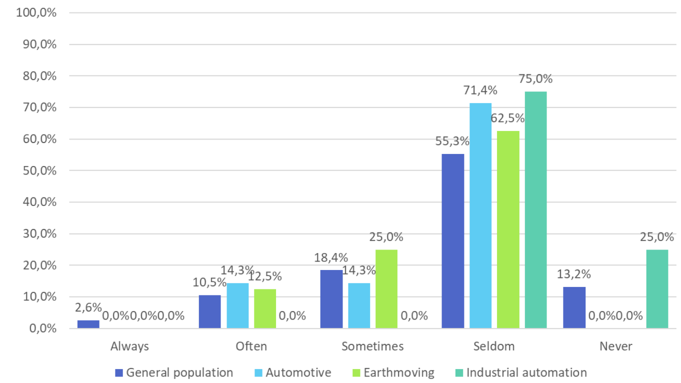

FIGURE 5: HOW OFTEN DO JOINT FAILURES HAVE THE FAILURE OF A THREADED CONNECTION AS THEIR ROOT CAUSE?

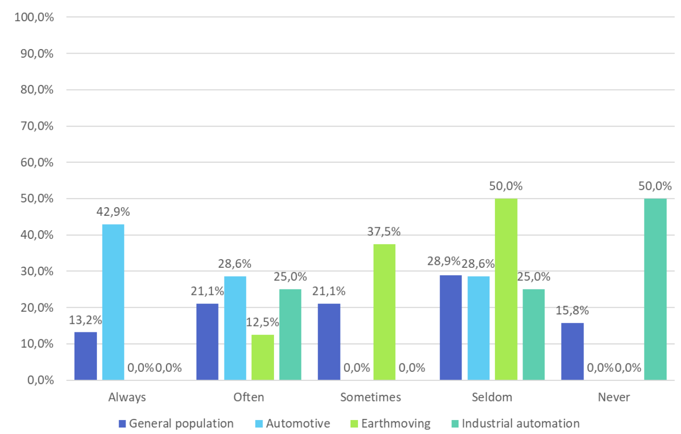

FIGURE 6: HOW OFTEN DO FAILURES IN THREADED CONNECTIONS RESULT IN SUBSEQUENT SYSTEM FAILURES?

When we shift the focus from mechanical joints as a whole to threaded joints, the picture looks more reassuring, as the histogram is shifted to the right for all industrial sectors, as shown in Fig. 5. One might conclude that this class of joints is less critical, but if combined with the histogram of Fig. 6, it appears rather quickly that threaded connections are likely to be a source of subsequent failure in machinery as a whole (answers *Always Often* and *Sometimes* total a remarkable 55.4%). Such figure becomes even worse if we narrow the field to automotive, where answers *Always* and *Often* alone (no *Sometimes*) total an astounding 71.5%. On the other hand, the earthmoving and industrial automation sectors seem to be comparatively less affected by failure propagated by faulty threaded joints. Finally, still limiting the analysis to threaded connections only, the respondents clearly indicated that the greatest part of failures are detected in-service. This outcome is a further warning about the threat posed by faulty threaded fasteners, due to the notorious safety and financial consequences of failures that are detected in the service life stage of a product. All in all, this part of the questionnaire highlighted that threaded joints may be less prone to failure with respect to other kinds of joints (adhesive?), nonetheless, their failure likely entails a fallout of consequences, especially in those fields where oversizing is not possible at all (e.g. automotive).

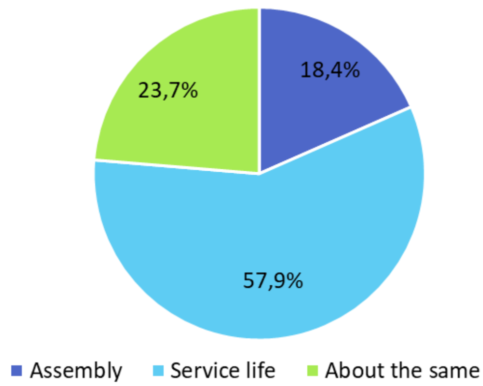

FIGURE 7: LIMITING THE ANALYSIS TO THREADED CONNECTIONS ONLY, AT WHICH STAGE DOES THE GREATEST NUMBER OF FAILURES OCCUR?

Fig. 8 and Fig. 9 represent the distribution of answers to questions relevant to failures that, among others, are more likely to be detected at the assembly stage. Focusing on overload at tightening (Fig. 8), inadequate lubrication is the only parameter that can clearly be identified in contrast to other root causes (11% *Always*), even if a substantial equilibrium among all possible root causes can be highlighted. As for Fig. 9, the picture is, again not perfectly clear, even if a certain prevalence of factors related to the incorrect specification or application of the tightening torque (13% and 16% *Often*, respectively).

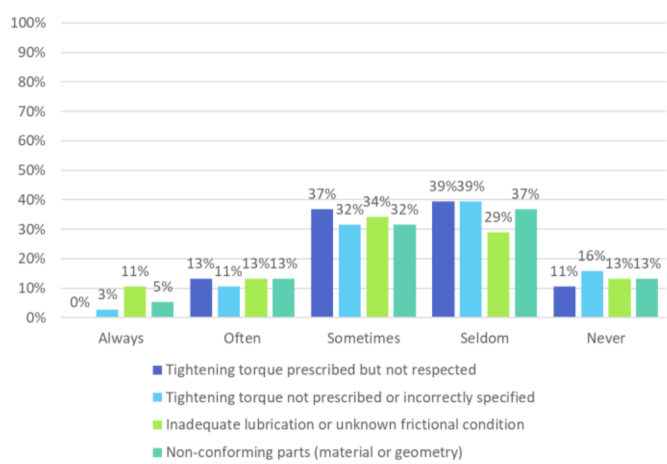

FIGURE 8: INDICATE THE FREQUENCY OF THE FOLLOWING ROOT CAUSES THAT TYPICALLY LEAD TO OVERLOAD AT TIGHTENING.

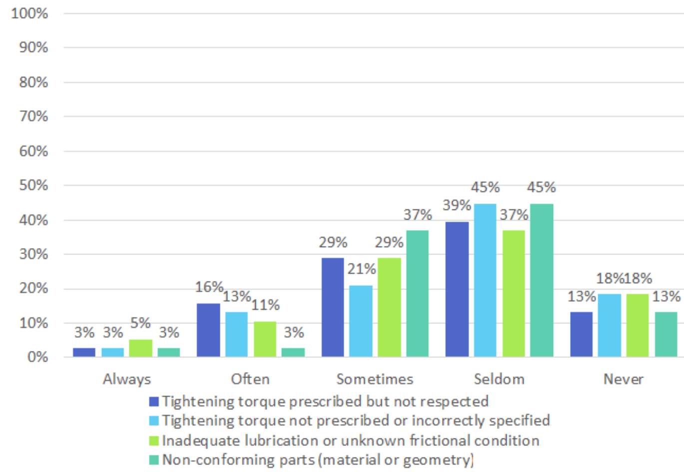

FIGURE 9: INDICATE THE FREQUENCY OF THE FOLLOWING ROOT CAUSES THAT TYPICALLY LEAD TO INSUFFICIENT PRELOAD AT TIGHTENING.

Figures 10, 11 and 12 show the root causes of failure that typically lead to in-service failure according to the following modes: overload (Fig. 10), fatigue (Fig. 11) and loosening (Fig. 12). According to the results shown in Fig. 10, the main element of relative concern is the knowledge of actual service loads (purple histogram shifted to the left in comparison to others). On the other hand, geometrical nonconformities of the parts appear as less likely to induce overload failure. Looking at Fig. 12, which summarizes the main root causes associated with fatigue failure of the joint, one can isolate a few prominent elements: (i) vibration loosening (42% *Often*), insufficient preload (13% *Often*, 26% *Sometimes*), corrosion (13% *Often*, 21% *Sometimes*). Focusing on loosening (Fig. 13), the main root cause is clearly recognized in vibrations (50% *Often*) and, in line with the literature, a low preload at tightening is expectedly found as a possible cause of preload loss over time (29% *Often*, 21% *Sometimes*).

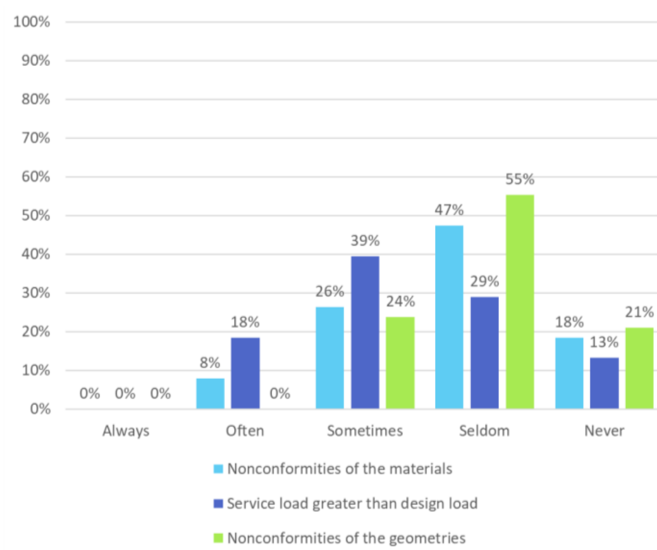

FIGURE 10: INDICATE THE FREQUENCY OF THE FOLLOWING ROOT CAUSES THAT CAN LEAD TO A SERVICE OVERLOAD FAILURE OF THE JOINT.

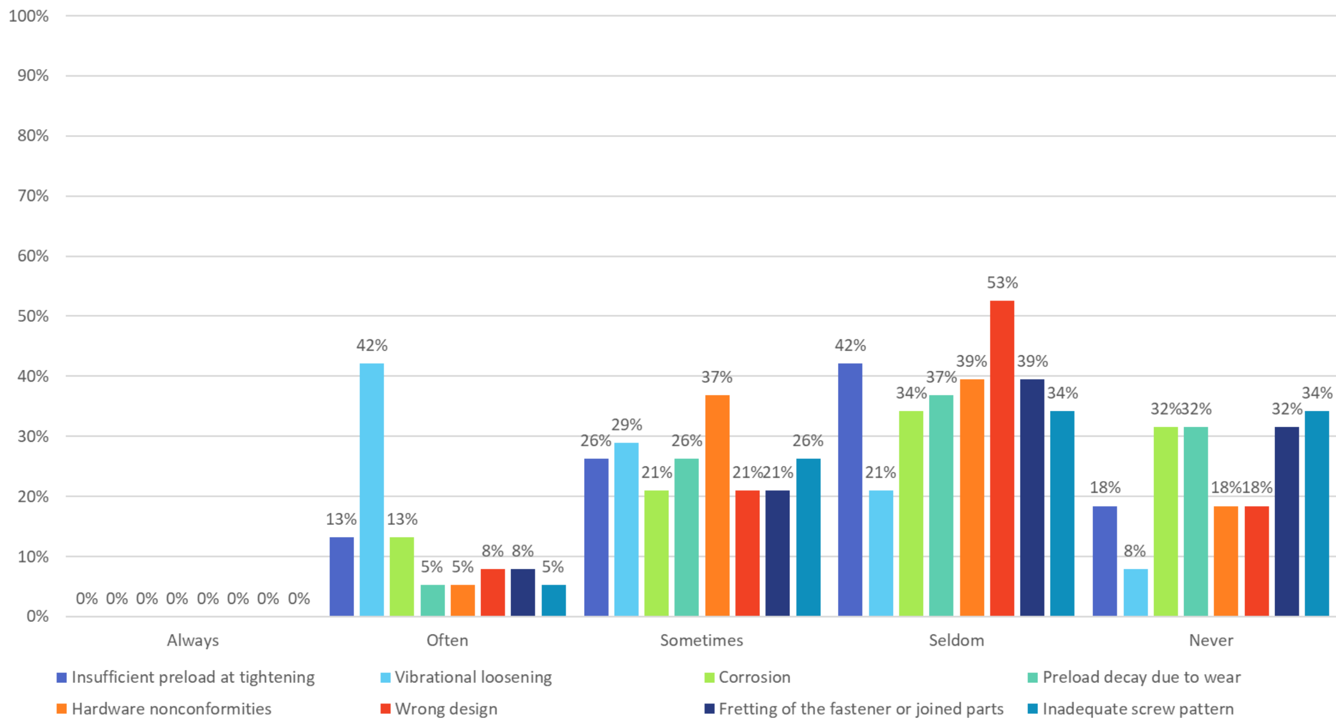

FIGURE 11: INDICATE THE FREQUENCY OF THE FOLLOWING ROOT CAUSES THAT CAN LEAD TO FATIGUE FAILURE OF THE FASTENER OR THE JOINED COMPONENTS.

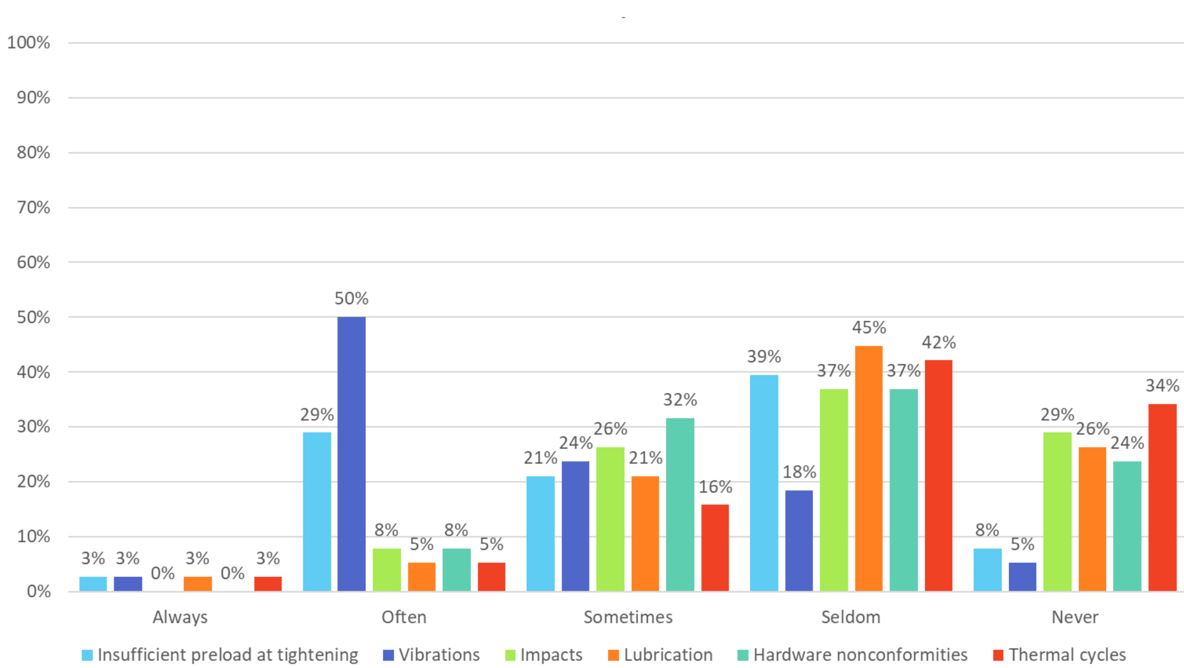

FIGURE 12: INDICATE THE FREQUENCY OF THE FOLLOWING ROOT CAUSES THAT CAN LEAD TO LOOSENING OF THE JOINT.

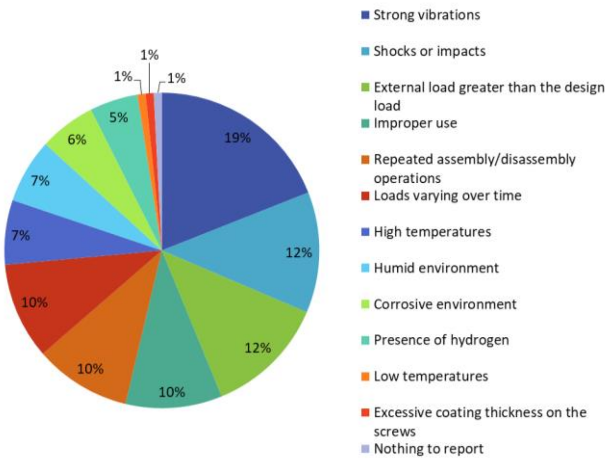

FIGURE 13: WHICH OF THE FOLLOWING ARE TYPICAL SERVICE CONDITIONS OF THE JOINTS THAT FAIL MORE OFTEN?

As a matter of fact, when inquired about the typical service conditions under which threaded joints are more likely to fail (Fig. 13), 19% of the respondents answered *Strong vibrations*, followed by *Shocks or impacts* with 12%. This outcome confirms that vibration loosening is a primary cause of concern in bolted joints. Looking at Figures 14 and 15, one can have a glance at the materials of the fasteners (Fig. 14) and joined elements (Fig 15) that fail more frequently: as expected steel plays a predominant role, mainly because of its prevalence as a construction material. Nonetheless, if we focus on the fastener material, stainless steel deserves a mention (23%), whereas, focusing on the joined elements (Fig. 15), i.e. plates or flanges, the second place belongs to aluminum components with 24%.

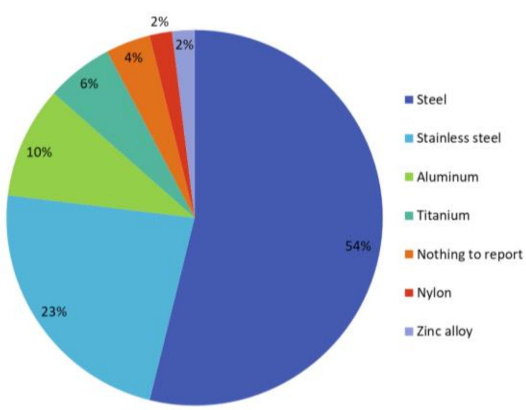

FIGURE 14: WHICH IS THE MATERIAL OF THE FASTENERS THAT FAIL MORE OFTEN?

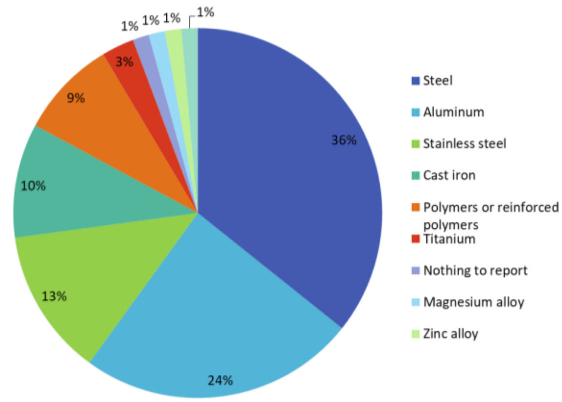

FIGURE 15: WHICH IS THE MATERIAL OF THE JOINED PARTS THAT FAIL MORE OFTEN?

When asked about whether the current number and placement of bolts could be the object of any improvements, the respondents gave the output shown in Fig. 16, where 55% of them confirmed the need for improvement.

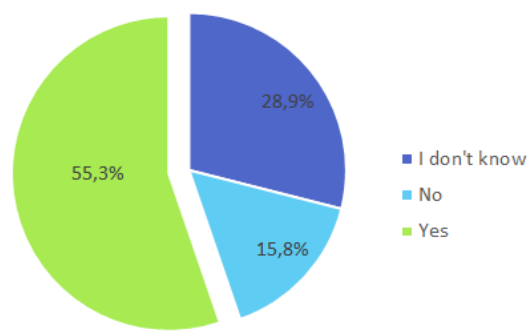

FIGURE 16: DO YOU THINK THAT THE CURRENT JOINTS CAN BE OPTIMIZED IN TERMS OF POSITIONING AND/OR NUMBER OF SCREWS?

CONCLUSION

This paper focused on the results of a survey that has been conducted on several Italian companies or Italian branches of multinational corporations, about the failure modes and associated root causes in threaded joints. The main outcomes of the study consist in: (i) a general acknowledgement of the criticality of mechanical joints as a whole, even if threaded connections seem to be less critical than other technologies; (ii) the tendency of threaded connections failures to generate subsequent failure, especially in the most mature sectors (e.g. automotive); (iii) the general tendency of fasteners related failure to be diagnosed during the in-service life of the machinery, with obvious fallout in terms of safety and cost; (iv) knowledge of the frictional conditions of the joint and respect of the tightening torque specifications are key to avoid failure in the assembly phase of the product (axial preload too high or too low); (v) fatigue failure is mostly traced back to previous loosening, insufficient tightening or corrosion; (vi) in service loosening is mostly related to strong vibrations, impact or insufficient axial preload. Further investigation will be needed to clarify all the relevant consequences and possible improvement actions (e.g. experimental activities and improvement of the assembly procedures).

ACKNOWLEDGMENTS

Even if, due to confidentiality reasons, it is not possible to cite all the respondents and the relevant companies, the authors would like to express to each one of them their gratitude for taking part in this important survey.

REFERENCES

[1] Avellon, G. Fastener Failures Prove Surprisingly Common in the Automotive Industry. 2014. Available online: https://boltfailure.com/fastener-failures-prove-surprisingly-common-in-the-automotive-industry/ (accessed on 26 January 2025).

[2] Epower Metals. Failure Analysis of Bolt Corrosion. 2020. Available online: https://www.epowermetals.com/failure-analysis-of-bolt-corrosion.html (accessed on 26 January 2025).

[3] QC-FIT Evaluation of Connector and Bolt Failures—Summary of Findings. 2014. Available online: https://www.bsee.gov/sites/bsee.gov/files/ (accessed on 26 January 2025).

[4] Croccolo D., De Agostinis M., Fini S., Mele M., Olmi G., Scapecchi C., Tariq M.H.B. Failure of Threaded Connections: A Literature Review, (2023) Machines, 11 (2), art. no. 212.

[5] Holmes, H. Seeking the Perfect Locking Method for Threaded Fasteners, Automation 35 (3), (1988), 28 – 30.

[6] Cloud, G. L. 2012 William M. Murray Lecture: Some Curious Unresolved Problems, Speculations, and Advances in Mechanical Fastening, Experimental Mechanics 53 (2013) 1073-1104.