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Decarbonising of the Indian Cement Industry Through Alternative Fuels – Challenge of Transfer Chute Jamming

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Abstract: The Indian cement industry in COP27 highlighted its commitment to achieving net zero CO_2 emission by 2070 made during COP26. The industry is moving towards decarbonisation and has identified various levers to achieve the goal. Fossil fuel replacement by Alternative Fuels (AFs) has been identified as one of the levers. Refused Derived Fuel (RDF), surplus biomass, industrial waste, and other societal wastes, etc., have emerged as potential AFs; however, their use comes with technical challenges like transfer chute jamming due to the wide range of variations in their properties. Jammed transfer chute leads to the breakdown of the entire transportation system and further fluctuation in AFs feeding to the kiln/calciner. Fluctuation in the feed rate of the AFs disturbs the fuel mix ratio (mix ratio of fossil fuel and AFs) and ultimately negatively impacts the process, operation, and quality of the produced cement.

Transfer chute design is often overlooked, leading to build-up, blockage, and wear in chutes. Designing of transfer chute is more challenging when handling solid alternative fuels in cement plants, as the properties of these fuels have a wide range of variation where moisture may be as high up to 40%, bulk density may vary from 0.1 to 0.75 tonnes/m^3, and particle size ranges from 1 to 100 mm, etc. This study covers a survey to establish which types of AFs, and their characteristics contribute to the chute jamming problem. The outcome of this study shall help the Indian cement industry to consider the appropriate inputs for transfer chute design and selection of the correct alternative fuels and their mix to avoid chute jamming.

Key words: Alternative fuels, cement plant, chute jamming, thermal substitution rate.

Introduction

The Indian cement industry, the second-largest cement producer globally, is sensible and accepts new challenges and targets for reducing its carbon footprint. One of the critical challenges received by the Indian cement industry is to achieve a 25% thermal substitution rate (TSR) through alternative fuels by 2025 (MHUA, 2018). However, due to various factors, the industry revised the target to achieve 25% TSR by 2030 (Mohapatra, 2022). The industry is a critical player in the circular economy by utilising the waste of other industries as AFs and alternative raw materials (Kukreja et al., 2020). Biomass, RDF, used tyres, and hazardous waste, have been identified as promising alternative fuels (CII, 2011). In COP26, India declared to adopt low carbon growth, switch half of its energy requirement from fossil fuels to non-fossil fuels by the end of the decade, and achieve carbon neutrality by 2070 (Modi's COP26 speech, 2021; Mohapatra,

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2021).To achieve such ambitious goals, the use of alternative fuels replacing coal in the Indian cement industry may play a vital role. Available AFs in India have different characteristics & physical properties, and handling these wastes as fuels with a single system is always a challenge. Various equipment and conveying systems are available, accommodating various types of AFs and their mix of varying physical properties. However, transferring material from one equipment to another through a transfer chute may lead to jamming issues if the chute is not designed according to AFs characteristics and equipment kinetic parameters (Kukreja et al., 2019). Although the transfer chute is a very low-cost item compared to the investment of a complete alternative fuel handling system yet, it may stop the complete system, once it gets jammed. Hence, the transfer chute demands adequate attention in the preliminary stages of system design. Unfortunately, transfer chute design is often overlooked, and a lack of understanding of the relationships between chute functionality- build-up, blockage, and wear are the results (Ilic, 2020). This study tries to find out which types of AFs and its characteristics contribute to the chute jamming problem. A survey is conducted to establish the chute jamming issue in the Indian cement industry and collect vital information to analyse the issue for further research and development work.

Literature Review

The application of alternative fuels in the Indian cement industry is not new; however, compared with the European countries, the industry started late with 0.6% TSR in 2010 and reached 5% TSR in 2021 (Mohapatra, 2022). The following graph (Figure 1) indicates the growth trend of TSR in the Indian cement industry in the last decade by utilising AFs in place of coal.

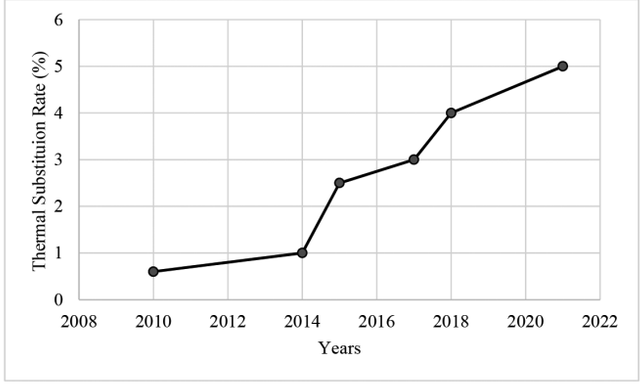

Figure 1: Thermal substitution rate in Indian cement industry (Mohapatra, 2022; Kumar et al., 2014; Saha and Karstensen, 2017).

From the above graph, it can be observed that the growth of TSR is not satisfactory when compared to the initial target of the industry, i.e., 25% TSR by 2025 (CII, 2011). Various reasons are contributing to the slow growth of TSR in India. It includes variations in the physical & chemical properties of AFs and pre-treatment issues, creating many technical challenges while handling and co-processing the alternative fuels in a cement kiln. Apart from technical issues, waste management legislation, inadequate local waste collection network, social acceptance, and complex bureaucracy are the main non-technical barriers to achieve high TSR (WBCSD, 2018). Transfer chute jamming has been identified as one of the significant technical challenges of system design while handling alternative fuels and their mix of varying physical properties. Bose (2019) reported a chute jamming issue due to high moisture while handling pharma waste as AFs in one of the cement plants. CII (2006) and CII (2011) prepared a manual on *"Best Practices in Indian & International Cement Plants"* in the year 2006, where jamming in chutes while handling AFR due to high moisture was highlighted. UTCL (2015), Vikram Cement Works also reported jamming of hoppers & chutes while handling MSW (RDF) as AFs during *Knowledge Exchange Platform 2015*, organised by the Bureau of Energy Efficiency India. SPEG (2016) also reported the problem of chute jamming while handling RDF in their experience report published in 2016. Deolalkar (2016), in his book *Designing Green Cement Plants,* also reported chute jamming issues while handling RDF, Hazardous waste, biomass, etc. Kukreja et al. (2022) published a case study for one of the Indian cement plants facing the issue of chute jamming while handling RDF.

Sufficient literature supports the chute jamming issue in Indian cement plants while handling alternative fuels. However, the literature is unavailable to establish which types of alternative fuels, and their physical properties except moisture are contributing more to chute jamming phenomena.

Survey Methodology

Selection of Parameters

From the discussion with the experts in alternative fuel system design and operation, various parameters like types of alternative fuels being used, technology suppliers, achievable TSR, chute jamming issues, characteristics of alternative fuels, etc., are noted. The parameters are then combined according to their nature.

The critical parameters considered for the survey have been shown in Table 1.

Table 1: Survey parameters

Survey parameters	*Details asked*
Alternative Fuels Details	• The primary type of solid alternative fuels • Alternative fuels (AFs) being fired in • Thermal substitution rate (Annual Average) % • Plant location • Name of technology supplier/s • Main equipment • Year of installation
Alternative Fuels Properties	• Bulk density range of AFs in t/m^3 (after pre-processing) • Moisture range of AFs in % (after pre-processing) • Particle size range of AFs (after pre-processing) in mm • Net calorific value range of AFs (kcal/kg) • The angle of repose range in degree
Alternative Fuels Nature	• Abrasiveness • Corrosiveness • Stickiness • Hazardous
Issues with Transfer chute	• Are you facing any problems with the transfer chute during the transportation of AFs? • If Yes, what kind of problem are you facing in the transfer chute • Anticipated reasons for problems • Annual hrs spent on maintenance of transfer chute • Plant team attempts in modification to improve the chute design? (If Yes, please describe in brief)

Survey Design

Since most of the criteria were technical, their evaluation was planned to be through a survey. The questionnaire was designed for the assessment of different parameters. Structured questionnaires were prepared, tested, validated, modified, and opinions were collected through a web-based survey. The experts were identified from the cement industry, cement design consultants, alternative fuels system suppliers, cement R&D centers, academicians, etc. Out of 148 cement plants (including 5 Clinkerisation units), around 60 cement plants use alternative fuels for co-processing (Mohapatra et al., 2019). Hence, a questionnaire was sent to all 60 plants and 40 consultants, R&D centers, AF system suppliers, academicians, etc.

Results and Discussion

Out of 100, a total of 61 responses were received, which is satisfactory survey research response rates (Fincham, 2008) and the classification of respondents in percentage is indicated in Figure 2.

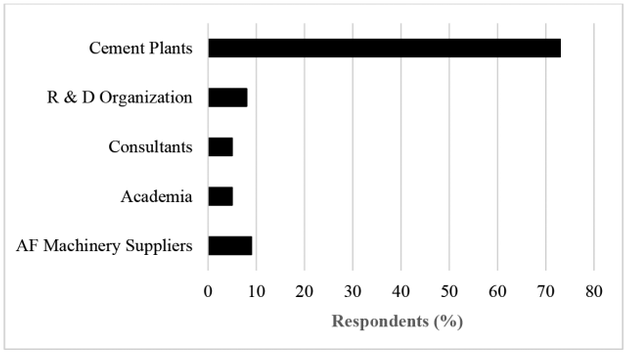

Figure 2: Classification of respondents.

The above classification indicates a sufficient representation of cement plants from India that use alternative fuels.

Survey Data Analysis

The advanced data analysis tool i.e., python programming language, is used for extensive data analysis to determine what type of alternative fuels are more responsible for chute jamming and what material characteristics lead to chute jamming issues. The raw data collected contains some null values. The data was then cleaned, and various feature engineering techniques were applied to the data using seaborn and Matplotlib libraries of Python. The data was visualised by plotting bar graphs against various types of fuels and transfer chute issues. Forty-eight respondents (78.7%) out of 61 confirmed the problem associated with transfer chute while handling alternative fuels (Figure 3).

Furthermore, 52 responses received related to the type of problem faced by the respondents in a transfer chute while handling alternative fuels.

Figure 4 indicates that jamming is a leading issue with transfer chutes, however, material plugging and spillage were also reported by a substantial number of respondents. Plugging or buildups also lead to chute jamming. Hence, more than 86% of total respondents are facing transfer chute jamming problems. The

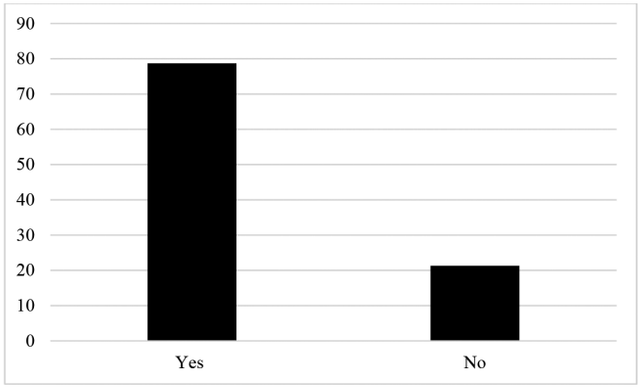

Figure 3: Problems in transfer chute while handling AFs.

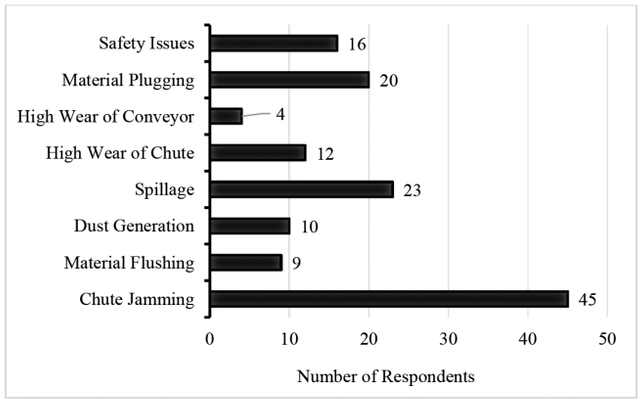

Figure 4: Issues with transfer chute while handling AFs.

industry is spending substantial time repairing and maintaining the chute (Figure 5). The unavailability of the material transport system due to the breakdown of the transfer chute not only involves the cost of maintenance but also hinders the plant operation due to fluctuation in the AF feeding rate, and ultimately variation in the fuel mix ratio.

After establishing that transfer chute jamming is a major issue, further survey data analysis was done to visualize transfer chute issues concerning various

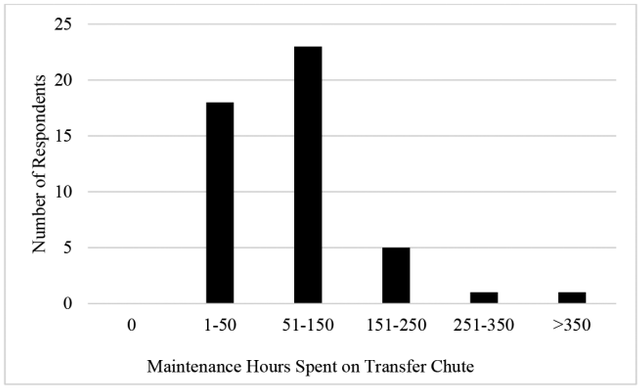

Figure 5: Maintenance hours spent on transfer chute.

alternative fuels. Figures 6 and 7 are self-explanatory and indicate the relation between the types of alternative fuels with chute jamming issues. It was observed that out of 25 cement plants that are using biomass, only six plants are having jamming issues, whereas out of 24 plants where biomass is not used, nine are facing the issue of chute jamming. Hence, biomass as AF is not a major contributor to chute jamming. Similarly, tyre chips are also not contributing to the chute jamming issue. However, RDF, mixed waste, industrial waste, plastic and sludges contribute significantly to chute jamming.

Further, a correlation heatmap was plotted to identify which type of AFs out of RDF, industrial waste, mixed waste, plastic, and dry sludges contribute more to the chute jamming problem.

The correlation heatmap (Figure 8) clearly shows that mixed waste fuel causes more transfer chute jamming problems, followed by industrial waste, plastics, RDF,

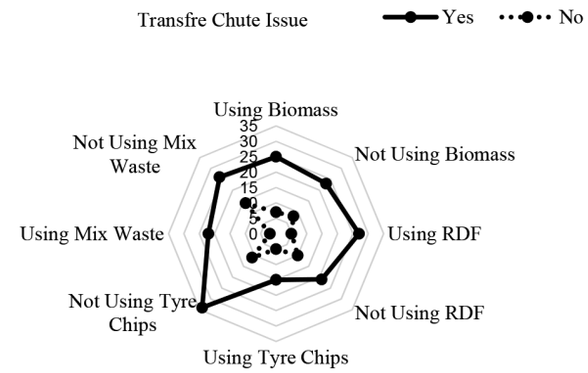

Figure 6: Interrelation of the use of biomass, RDF, tyre chips, mix waste with chute jamming.

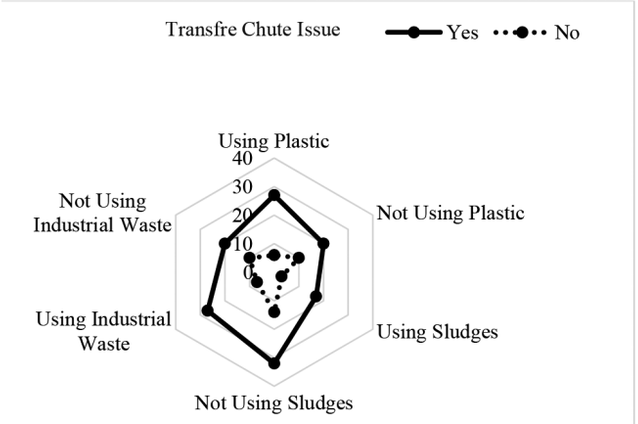

Figure 7: Interrelation of the use of plastic, sludges, industrial waste, with chute jamming.

Transfer Chute Issue	1	0.18	-0.02	0.3	0.18	0.16	0.14
Industrial Waste	0.18	1	-0.28	0.4	0.12	0.15	0.2
Tyre Chips	-0	-0.28	1	-0.08	0.06	-0.3	-0.1
Mix Waste	0.3	0.4	-0.08	1	0.02	0.17	0.13
Plastic	0.18	0.12	0.06	0.02	1	0.09	0.2
RDF	0.16	0.15	-0.33	0.17	0.09	1	0.36
Dry Sludge	0.14	0.2	-0.12	0.13	0.2	0.36	1
	Transfer Chute Issue	Industrial Waste	Tyre Chips	Mix Waste	Plastic	RDF	Dry Sludge

Figure 8: Correlation heatmap of different AFs with transfer chute jamming problem.

and dry sludges. From the same correlation, it can also be noted that mixed waste and industrial waste are highly correlated, and if these two fuels mix, it causes more chute jamming problems. Similarly, the chute jamming issue will increase if RDF & dry sludges are mixed together. Data is further analysed to understand which characteristics of the alternative fuels (*corrosiveness, stickiness, abrasiveness, hazardous*) cause more chute jamming problems. The result is shown below (Figure 9).

From the above figures, it can be inferred that the sticky nature of fuel is a major cause of concern related to the transfer chute jamming issue.

Furthermore, the respondent also shared the anticipated reasons for chute jamming and their efforts to resolve the transfer chute jamming issues. A total of 50 responses were received to share the anticipated reasons for chute jamming and the majority

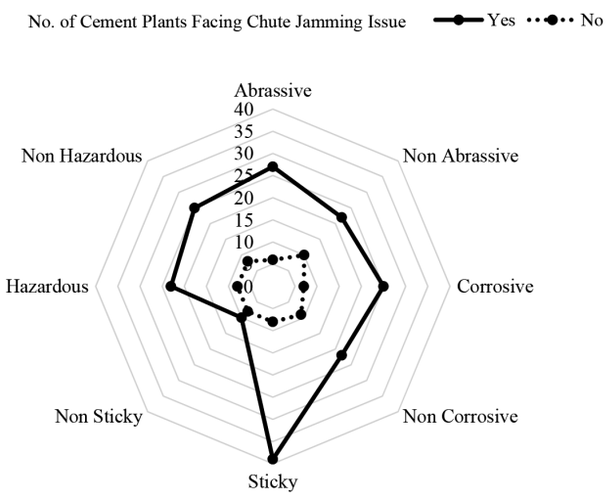

Figure 9: Relationship of AFs characteristics with chute jamming.

Table 2: Efforts made by respondents to avoid the chute jamming

SN.	*Efforts made by respondents to avoid the chute jamming*	*Remarks by author*
1	Chute inclination increase	Depending on the existing layout
2	Falling height changed	Depending on the existing layout
3	Change in mass flow rate through the chute	Not advisable as the reduction in flow rate, reduces the TSR
4	Installation of air blaster in transfer chute	Not advisable as it is energy-intensive equipment and is not effective when the cake formation of AFs in the transfer chute takes place
5	Electric hammer fitted on chute wall	Not advisable, as it may damage the chute wall mother plate as well as the liners
6	Provide stainless steel liners to improve the flowability	Adequate liners improve the flowability of material if the other parameters of the chute design are accurate like chute width, inclination, cross-sectional area, exit opening, etc.
7	Bend removed from the transfer chute profile	Depending on the existing layout
8	Installation of chute jamming sensors	A preventive option but not much effective in AFs handling

of respondents shared that adoption of a conventional method of chute design (used for limestone, coal, and other additives), ignorance of input properties of AFs at the design stage and introduction of new AFs have been the major cause of chute jamming. Furthermore, 29 respondents shared their efforts to resolve the transfer chute jamming issues at their level, Table 2, indicates the list of major changes adopted by respondents and the view of the author-

Table 1 indicates that suggestions/modifications suggested by respondents are focused on preventive maintenance steps like installation of air blasters, electric hammers for chute cleaning, and sensors that detect agglomeration and jamming of the transfer chute handling alternative fuels followed by the design medication suit to the site requirement. However, improvement in the design of transfer chute handling AFs at the stage of design & engineering to mitigate its jamming has not been perceived earlier.

Conclusion

With the help of advanced analytical techniques, survey data has been analyzed, and it is found that alternative fuels such as mixed waste, industrial waste, and RDF are the leading cause of concern for chute jamming. These AFs are being prepared by mixing various wastes either at the cement plant level or at the pre-processing station to achieve desired properties (*mainly heat value and other properties like chlorine content, moisture, etc.*) of alternative fuels. The properties of these three wastes are variable and inconsistent due to the heterogeneous nature of the mix, which leads to difficulty in the flow of materials at transfer points. Further, mixing RDF with dry sludges and mixed waste with industrial waste may increase the tendency of chute jamming. Lack of consideration of the properties of these wastes while designing the transfer chute may be one of the reasons for the jamming issue.

On the other hand, the stickiness of the materials is characteristic of these AFs, contributing to the jamming issue. It may be one of the reasons that plants are not using flow assistance liners. It can be concluded that despite the very low-cost component of the material conveying system, the transfer chute is creating a major hindrance in achieving high TSR, and it is a must to address this issue at the design & engineering stage of the project to avoid breakdown of complete alternative fuels system. The outcome of this study shall help the Indian cement industry to consider the appropriate inputs for transfer chute design and selection of the correct alternative fuels & their mix to avoid chute jamming.

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