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Review article

Sand screens application and performance for sand control: A review of selection criteria, screen materials, and causes of failure

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ABSTRACT

Production of sand from oil and gas wells necessitates the application of techniques for sand control. Sand screens are widely used. However, they are susceptible to failures, often stemming from improper selection and design. This study reviews existing selection criteria and identifies the causes of failures. It has been concluded that, sand screens selection should not rely on a single method but should consider a comprehensive combination of factors. This paper presents comparative analyses among various sand screen types. Also, it compares different materials used in sand screens, such as expandable, ceramics, metallic alloys, polymers, and shape memory materials, in terms of their performance and susceptibility to failure. These comprehensive comparisons can greatly assist in the optimized selection process for sand screens.

1. Introduction

In the production of oil and gas from sandstone reservoirs, sand is typically extracted alongside formation fluids. As sand particles flow through the production equipment, they continuously collide with the inner surfaces of pipes and other components. The consequence of these impacts result in the removal of material from the exposed surfaces due to erosion, which, in extreme cases, can lead to equipment failures. As oil and gas production continues for long durations, the production of sand particles significantly impacts the integrity of petroleum production systems, because huge amounts of sand might flow through pipes. Therefore, it is vital to implement sand control methods to prevent the movement of sand from wellbores to the surface. Nonetheless, there is no universally effective sand control method that can be applied to all types of unconsolidated sandstone reservoirs [1]. Also, when down-hole sand control fails to work as intended, the sand produced will find its way to the surface, which causes piping and surface facilities to erode, leading to malfunctions and deposition issues. The stand-alone screen (SAS) is a commonly employed sand management method that offers dependable control at a minimal cost and with minimal complexity. However, sand particle passage and impingement may also have an impact on SAS application, potentially leading to erosion and failures.

Looking closely at different sand screens, each is unique for different purposes, according to Romanova et al. [2], the wire-wrapped

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screens (WWS) are not too dependent on the particle size distribution unlike slotted liners (SL) due to their aperture width that accommodates a wider range of PSD and hence could be said to outperform SL. Furthermore, Arumugam et al. [3] study on sand screens suggested that when considering sand retention, premium and metal mesh screen are more reliable than wire-wrapped screens at an increased flow rate. This justifies their common use in unconsolidated formations. However, wire wrapped is known to have a lower tendency to plug, unlike premium and metal mesh Arumugam et al., 2019. While making these considerations, operators also consider the cost which is also essential in optimization. According to Ismail et al. [4] premium square mesh screens (SMS) and converging slots screen (CSS) provides greater retention efficiency than WWS when considering the slot/pore width per mean particle diameter (w/D), however, at a point when the w/D is greater than 2 the sand retention in CSS gets difficult and WWS and SMS now tend to be better. These specificity changes across sand screens and informs the choices made by operators and because of this, Numerous authors have investigated the factors contributing to screens failure, and a majority of them have reached the consensus that erosion stands as the predominant cause. In this study, sand screen types and selection criteria will be introduced and explained, this will be followed by sand screen performance and causes of failure.

2. Stand-alone screen types, selection criteria and performance

2.1. Sand screen types

SASs are an attractive choice for controlling sand, due to their cost-effectiveness and ease of installation. SAS employs mechanical retention to obstruct the movement of sand towards the well. That is, sand will be stopped and only fines (small particles) will pass through the screen [5]. According to Ahad et al. [6], SASs and gravel packs are the most appropriate technique for reservoirs with unconsolidated sands. There are several types of SAS as shown in Fig. 1.

SAS types differ in terms of their design, characteristics, and applications. Premium screens with multiple layers are characterized by stacked layers of filtration media, such as woven mesh or sintered metal, with each layer offering different pore sizes and filtration efficiencies. They are preferred in wells with high sand content [7,8]. However, wire-wrapped screen is composed of an external casing manufactured using specialized wrapping machinery resembling a lathe. During fabrication, the wire is shaped and affixed to longitudinal rods, creating a singular helical slot of adjustable width. Following this, the casing is positioned over and welded at both ends to a supportive pipe base, which contains drilled holes, ensuring structural reinforcement. On the other hand, slotted liners are produced from tubular materials by cutting slots using saws. The width of these slots is commonly measured using gauge units. This gauge is essentially the width of the slot opening in inches multiplied by 1000. For example, a screen with a 12-gauge designation indicates openings measuring 0.012 inches. Prepacked screens are an adaptation of wire-wrapped screens, serving as a modular gravel pack solution [9,10]. They comprise a typical screen assembly encased in an annular ring, containing resin-coated gravel, which is supported by either a second screen (dual-screen prepack) or an outer shroud (single-screen prepack) [11].

According to Riyanto et al. [12], the major challenge associated with SAS is screen erosion and methods are being introduced to improve screens which led to the development of Ceramic Sand Screens, and the use of alloys and exotic materials (shape memory screens, expandable sand screens ESS, etc.) to improve the surface structure for resisting erosion.

2.2. Sand screens' selection criteria

Selecting the appropriate sand control method is based on the particle size distribution (PSD) of the formation's grains and on other production and reservoir parameters. In terms of PSD, the selection criteria by [13] are among the earliest criteria proposed (Table 1), based on which the screen selection is related to fines content (which represents the mass fraction of particles less than 44 μm), uniformity coefficient (UC), and sorting coefficient (SC).

Tiffin criteria have been accepted for some time, which is however later challenged by several authors including [14] and Mathisen et al., [15]. They cited successful SAS field applications in more than 200 wells in which Tiffin's criteria indicated the application of open whole gravel packs (OHGPs) because of high UC, SC, and fines content. In addition, Slayter et al. [16] criticized the fines definition, stating that they should only be defined as fines if their size is small enough to flow through the pores of the undisturbed matrix. Chanpura et al. [17] challenged Tiffin's criteria with experiments, which revealed that 30 of 45 WWSs and 70 of 140 metal mesh screens (MMSs) having UC values (5–26), satisfied a very conservative sand retention criterion. Here, note that those UC values

(1) (2) (3) (4) (5) (6)

Fig. 1. (1) and (2) Premium screens with multiple layers, (3) wire-wrapped screen, (4) basic screen, (5) slotted liner and (6) prepacked screen [6].

Table 1
Sand control selection criteria proposed by Tiffin et al. [13].

D10/D95 Sorting coefficient (SC)	D40/D90 Uniformity coefficient (UC)	Sub 44 μm or'fines' (%)	Proposed completion system
<10	<3	<2	Screen only
<10	<5	<5	Premium screens
<20	<5	<10	Gravel packing
>20	>5	>10	Wellbore enlargement (horizontal and fracture)

(5–26) are well beyond Tiffin criteria for SAS applications. Parlar et al. [18] considered Tiffin criteria to be not justifiable to disqualify SAS and proposed practical implementation limitations if the following were needed from the design parameters: (1) Required opening are too small to be manufactured; (2) susceptibility to plugging during installation and prevention cost could be higher than gravel packing, i.e. high cost of or impracticality of mud conditioning or solid-free fluids; (3) intolerance to transient sand production before natural sand pack establishment; (4) very laminated formation having movable shale streaks difficult to be isolated using packers and (5) the strength of formation and the possibility of failure. Parlar et al. [18] agreed with [19] that to have successful application of SAS, pre-completion and completion operations are to ensure minimal plugging during installation such that screens effectively retains the sand with a small pressure build-up rate. Nevertheless, some of the considerations of excluding SAS proposed by Parlar et al. [18] are case-specific and cannot be generalised, for instance considering factors such as cost as it varies with time. For example, Ojeh-Oziegbe et al. [20] described successful application of single-trip SAS (STC-SAS) in Bonga deep-water reservoir. The primary reason for adopting STC-SAS was its potential to reduce rig completion time by around 50 % when compared to traditional multi-trip SAS completions, resulting in significant cost savings. Zeidan et al. [21] described a field that was completed successfully using vertical-cased SAS although it was initially designed for gravel pack completion given that the sand's PSD result has shown high percentage of UC (7.5 %) and high fine sands (11 %). The decision of implementation was made according to detailed analyses on the formation's sand, screen design, and the completion fluid during the installation of SAS.

One possibility of such differences is that the selection could have been based on PSD data that might not have fully represented reality. Therefore, the accuracy of determining the PSD of the formation sand is necessary. According to Zhang et al. [8], any inaccuracy in determining the PSD might result in improper screen and/or gravel size selection. Furthermore, inaccurate presentation of PSD might result in testing sand particles which do not represent the original formation sand, hence potentially resulting in the selection of an incorrect screen size. The two most commonly used techniques for determining the PSD of formation sand are laser particle size analysis and dry sieve analysis. Nonetheless, it is well-known that these two techniques reportedly have differences in PSDs [16,22,23].

Using screens for sand control is a matter of the relation between particle size and screen slot width. The screen selection aims to find screens that efficiently retain sand and at the same time maximize production, by choosing the optimal sand screen opening and evaluating the limitations that occur during sand retention tests [24,25]. Screen retention laboratory tests are often conducted to guarantee that the screen is compatible with the reservoir. There are two categories of sand retention tests that are commonly adopted, namely prepack and slurry sand retention tests. Slurry tests are conducted to replicate the conditions of gradual sand production, where there is an open annulus between the sand face and the screen. Conversely, prepack tests are designed to mimic conditions where no such annulus is present. However, Wu et al. [25] stated that no agreed standards exist in the industry regarding the methodology of conducting sand retention tests and interpreting the results. The future perspective of selection based on simulation according to different parameters, if validated with experimental tests, will open new opportunities for experimental techniques on screen and gravel pack selection [6].

As with the importance of understanding the PSD of the reservoir for choosing the appropriate screen type and screening method, the material used in the construction of screens has also been emphasized as a critical factor in the screen selection process. Apart from identifying SAS based on the type as seen in Fig. 1, they can also be defined based on material type. For example, in high-temperature high pressure HTHP wells with potential caving issues, ceramic sand screens were chosen instead of slotted liners due to their erosion, corrosion, and heat resistance, and self-propagating high-temperature sensitivity (SHS), [26]. Like ceramic sand screens, screens made of steel, titanium alloys, Inconel, and polymers exhibit unique characteristics and responses to erosion and various downhole

Table 2
Sand Screen Material selection considerations.

Material Type	Property	limitations	Ref.
Ceramics	High surface hardness, corrosion resistance, erosion resistance, and high melting temperature.	Not ductile, brittle, plugging, reduced production	[26,27]
316 stainless steel wire mesh sand screens	Corrosion resistance, ductile, high toughness, erosion resistance	Erosive wear is angle-dependent for ductile materials, micro ploughing and pitting wear are significant	[28]
Titanium alloys	Corrosion resistance, tough, ductile, erosion resistance	More erosion is noticed at higher velocities with low angles unlike low impact velocities and high impact angles	[29]
Mild Steel	Erosion resistance, high tensile stress, ductile	On an increasing impact time, cracks develop on screen surfaces, and poor corrosion resistance	[30]
Poly-chloroprene rubber	Low melting point, erosion resistance, less dependent on impact angles, ductile,	Used at low temperature zones, extended drags after impact, particle impingement	[31]

conditions. Table 2 shows specific properties of different material types that will influence the choice of sand screens in an oil and gas well.

Table 2 provides a review of various materials used for sand screen manufacturing. It is evident that all these materials possess some level of erosion resistance. However, what differentiates them is the degree of this resistance. Moreover, each material exhibits distinct properties that render them more or less susceptible to specific conditions. For example, temperature could be used as criterion for considering ceramic sand screens over polymer or mild steel. However, if the target is the ductility or level of energy absorption, more ductile or tougher materials will be selected. Table 2 highlights the ongoing material enhancements to address sand screen erosion, with particular attention to material response, especially surface properties. It should be highlighted here that, few research has been done on the use of shape memory materials (SMM) such as shape memory polymers (SMP) and shape memory alloys (SMA) as sand screens to produce oil and gas [32]. However, they have been applied in aerospace, robotics, electronics, civil, medical and automobile industry [33]. The higher strain recovery during SME makes SMP ideal for developments of packers and sand management in downhole [34,35]. The self-healing properties of SMMs present breakthroughs for future studies. NiTi, NiTiHfPd, CoCrAlSi, Fe–32Mn–6Si, and TiNi3 are some SMAs that are proven to exhibit shape memory effect (SME) due to vibration, thermo-elasticity, thermal and stress induction [34,36–40], while SBS + PCL, MWNT, PU-SMP, CFRP are SMPs that have shown SME due to electro-active, temperature, and thermomechanical forces ([41–43]; H. [44]). Most of the properties are directly related to experiences during sand screen control in both oil and gas wells. The effectiveness of these materials would add more variety to the criteria of sand screen selection based on materials. Moreover, understanding the type of sand screen and how it performs enables operators to optimize operations and reduce sand production.

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There are different criteria by which sand screens are designed. For instance, Coberly [45] suggested that spherical particles can be retained if the slot size is 2.5 times the diameter of the particle or smaller. For mixed particle sizes, he stated that screen properties depend on the largest particles. He also proposed that screens should be sized with slots that are two times $> D_{10}$ of the formation sand. Markestad et al. [46] criticized Coberly [45] and showed that Coberly's [45] design criterion, or any other single-point-based criteria on the PSD curve, cannot effectively describe either plugging or sand production of single-wrapped screen. Therefore, by introducing a fractal PSD description of the formation sand and applying multivariate analysis, they developed a quantitative method for sizing slot widths. Their approach recognizes a safe range of widths such that plugging, and sand production are unlikely to happen. However, Markestad et al. [46] highlighted that their study focused on one type of screen, which is single-wrapped screens, and screen erosion was not considered. Recently, Li et al. [47] prop osed a protocol for sand control by screens, named holding coarse expelling fine particles (HCEFP). Their protocol is considered an optimization technique for sizing screen mesh for reservoirs of clayey silt hydrate.

The design criteria for each category of sand screen may differ depending on variables such as well conditions, sand particle size, and PSD. For example, Gillespie et al. [48] suggested that $2D_{50}$ serves as the maximum aperture size for wire-wrapped screens, based on slurry SRT across various sand types. Ballard & Beare [49] integrated findings from pre-packed and slurry SRT analyses to propose aperture sizing based on the D_{30}, indicating its superiority over the D_{10} criterion. Similarly, Weatherford guidelines advocate for D_{25} when selecting wire-wrapped screens. Several design criteria have been established for optimizing the design of slotted liners. Coberly [45] introduced the initial criterion for selecting the aperture size of the screen, which is based on the particle size distribution (PSD) of the formation. Based on experimental tests conducted using a single-slot coupon, Coberly determined that the aperture size must be less than double the D_{10} of the formation sand (the sieve size retaining 10 % of material mass) to establish a durable sand bridge. Afterward, numerous researchers examined and put forward design criteria for slotted liners across different applications, while others conducted prepacked sand retention testing experiments to ascertain the appropriate slot size [50].

2.3. Sand screen performance

SAS can have reliable control with less cost and complexity in open-hole environments if selected properly, particularly for horizontal or highly deviated open-hole completions. Generally, it can be agreed upon that there is no global agreement on what the right procedures and environment are for the successful applicability of SAS [51]. Even if there an agreement exists on the SAS applicability for a specific distribution of sand size, there are substantial variations in the suggested type of screen and opening size among laboratories. According to Wu et al. [25], Sand screen performance is usually evaluated according to two criteria: screen plugging and sand retention. That is, a screen should last longer before plugging and should attain the highest retention while preventing significant sand passage. Furthermore, produced sand size is also considered an essential factor in terms of erosion of production facilities. Table 3 shows the criteria for the acceptable performance of the sand screen.

3. Sand screen integrity and failure

3.1. Causes of failure

There are many causes of failures of completion during production. Wong et al. [56] summarised the causes as follows: (a) erosion of screen, (b) corrosion of screen, (c) localized flow 'hot-spots' arising after screen plugging, (d) hot-spots resulting from improper gravel packing in the annulus, (e) collapse of the screen as a result of compaction, (f) Annular pack destabilization caused by high velocity flow from the perforations (at casing ID) and (g) collapse of screen caused by plugging, etc. Furthermore, Wong et al. [56] suggested that the dominant modes of failure depends on the considered completion type. For cased-hole gravel packing, the predominant failures are associated with annular pack destabilization and screen erosion. According to Ma et al. [57], the packing density of gravel layers also influences sand control failures. When the gravel layer's percentage packing density decreases, sand control failure is more likely to occur; however, increasing the gravel layer's packing density by up to 68 % improves sand control. For cased-hole expandable screen, the failure cause is screen erosion. Many authors have examined causes and failure modes of SAS. Most of these studies concluded that screen erosion is by far the most common failure mechanism [58–60]. Screen erosion is due to the mechanical wear of the retention media, weave or wire. It can result in creating holes where sand can easily enter the wellbore.

Musa et al. [61] conducted a study because of the failure of a conventional metal sand screen in an offshore gas well in Bintulu field located in Sarawak, Malaysia. The PSD analysis of the produced sand found to be larger in size comparing with the size of the down-hole screen, which indicated a screen failure. The failure was assumed to have occurred because of erosion caused by high gas velocity. Nandogongar et al. [62] provided an overview of various failed sand control equipment removal and replacement techniques for workovers and the majority of pulled screens appear to have failed because of fluid erosion. Hamid & Ali [63] showed failure by erosion of screen which caused holes as shown in Fig. 2 which happened during high-rate water pack jobs. From Figs. 2 and 3 of eroded screens, it can be clear that erosion is localised in particular areas. According to Wong et al. [56], samples of recovered eroded screens usually depict localised erosion. Deng et al. [64] highlighted that, ultimately, erosion can result in localized damage to the screen, leading to the damage of sand control. An example of such damage is depicted in Fig. 4, showing a damaged metal mesh screen (MMS) in the oilfield.

There is another problem which is plugging that occurs when fines are produced. Consequently, inflow area will decrease, and skin effect will increase over time. There are cases where SASs were not successful because of plugging-associated problems, productivity decline and high-velocity areas that cause screen erosion. For instance, in the Champion field of Brunei Shell Petroleum (BSP) with highly deviated wells. Because of the issues during the installation of SAS, BSP set the decision of installing an open hole gravel pack (OHGP). According to van Vliet et al. [65], the motivation for installing OHGP's in deep-water wells was to secure long-term productivity by minimising plugging of screen, which might cause (1) decline on productivity owing to reduced inflow area and (2) the formation of localised high-velocity areas in unplugged portions of the screen, which consequently can lead to screen erosion. Li et al. [66] conducted a case study on a clayey silt hydrate reservoir. Their results revealed that total solid retention through a SAS is not often favorable because productivity may be affected by high contents of clay, as a result of extreme plugging. Screen plugging is always likely to occur, with the severity effect depending on the degree of mud mixing with formation sand. If the screen size was incorrectly designed such that narrow slot is selected, the finer particles could not be produced and could potentially cause pore throats plugging of the formation near the wellbore [67]. For single wrapped screens, plugging severity and slots width which could be plugged depend on the PSD of the sand [46]. Plugging likelihood was high when the flow at a relatively high rate was started suddenly [51]. illustrated by experiments the potentiality of screen plugging, even if conditioned mud was used during screens installation. They conducted two groups of experiments on eight-gauge wire-wrap screen (~200 μm slot openings). Those tests suggested that starting production from a well with conditioned fluids which contain considerable particle content might be a proposal with high risk, unless well bean-up is conducted to ensure the production of conditioned fluid in the screen open hole annulus before substantial sand production from around the screen. According to Parlar et al.,[68], wire-wrapped screen (WWS) has the advantage that it is most difficult to plug, however, has less erosion resistance. Moreover, inaccurate wire spacing can allow formation sand to be produced or scree to be plugged. However, Mahmoudi et al. [69] from their investigation on samples of wire wrap screen that, substantial plugging was found on the annular between the screen and the base pipe. Extensive accumulation of clay or fines in the annular space has led to partial or complete blockages in certain sections. Moreover, Mahmoudi et al. [69] studied several failed standalone screens that were collected

Table 3
Criteria for screen performance.

Reference	Sand production	Plugging of screen	PSD
Hodge et al., [52]	$\leq$ 0.12 lbm/ft^2 of flow area	$\geq$ 50 % maintained permeability	–
Adams et al., [53]	$\leq$ 0.15 lbm/ft^2 of flow area	$\geq$ 50 % maintained permeability	–
Williams et al., [54]	$\leq$ 6 % in effluent	<100 psi across sand pack & screen	$D_{50} \leq 50$ μms
Constien & Skidmore, [55]	$\leq$ 0.12 lbm/ft^2 of flow area	$\geq$ 50 % maintained permeability	$D_{50} \leq 50$ μm

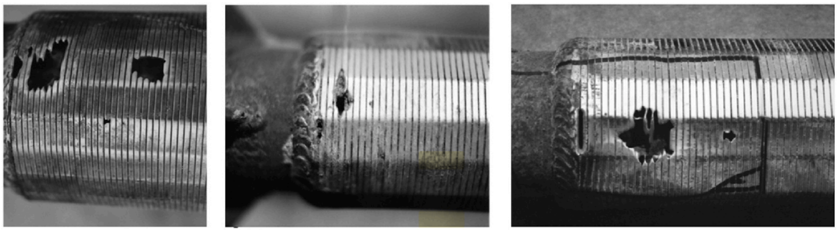

Fig. 2. Erosive failure in a HRWP [63].

Fig. 3. Erosion of sand screen Matanovic et al., 2012.

Fig. 4. Failure of metal mesh screen (MM S) [64].

from different fields and operational conditions. The screens/liners were cut into sections to be examined by SEM-EDX, X-ray micro CT scan, reflective light microscopy and petrographic thin sections for better understanding of the localized plugging mechanism. Fig. 5 shows partial plugging of the wire wrap with a patchy scale layer over the screen.

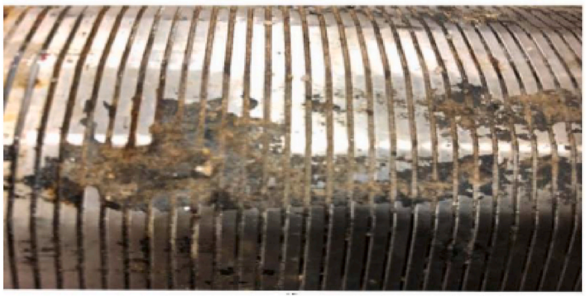

Fig. 5. Partial plugging of the wire wrap with a patchy scale layer over the screen [67].

On the other hand, Gjedrem [70] found that high annular velocity tends to cause of extreme screen erosion and using gravel pack to reduce can successfully protect the screens from erosion [70]. also concluded that expandable sand screens (ESSs) and SAS do not provide effective resistance against sand erosion. That means gravel pack and sand screens are sometimes used to eliminate annulus and create larger areas for particle filtration.

From the above, plugging and high annular velocity is shown to be from the major causes of sand screen erosion. Now, can sand screen still be eroded even after using gravel packing along with screens? What are the possibilities that fine particles cause erosion? Moreover, what are the mitigation methods against erosion due to high annular velocity and high localised hotspots? In an ideal scenario, the erosion level should decrease due to the protective effect of the gravel layer. Nevertheless, there are instances, as documented by Procyk et al., [71] and Fucheng et al., [72], where sand screens experienced erosion even after gravel packing. Gravel pack and ESS have also limitations, particularly in instances involving extended reach wells and various types of multi-lateral well configurations [59].

Matanovic et al. [7] described the reliability of stand-alone, expendable screens and slotted liners and showed that they are poor in heterogeneous formations but could be enhanced through inflow control devices (ICDs) and better testing. And as far as productivity is concerned, they can give highest productivity if no plugging is encountered. Additionally, the major shortcoming is that zonal isolation might be problematic that can cause plugging and screen collapse, damage or erosion during installation. However, according to Zamberi et al. [73], despite the technical challenges associated with SAS, its application in horizontal open hole completion as opposed to gravel pack can greatly cut down on capital costs and improve productivity. Parlar et al. [18] indicated the advantages and disadvantages of conventional sand control methods. Here only the comparison for sand screens is displayed in Table 4. As shown, plugging and erosion tendency is different across various types of screens. For instance, due to the high flow area of wire-wrap screens and premium screens, they have good anti-blocking characteristic, though their application is usually constrained by their cost especially in [11,74]. According to Manning et al. [75], ceramic screens are much superior in resisting highly erosive environments when compared to metallic screens. Their resistance extends the timeframe of downhole sand control where high velocity flow would cause metallic screens failure through accelerated erosion due to hot spots [75].

There is a thin line between performance and cost, of which the operator of such a tool (in this case sand screen) gets to make an optimal decision to suit the production operation. Owning to this premise, suggestions could be made on the outcomes of Table 4. For example, the erosion resistance of wire-wrapped screens could be improved by Inconel materials with considerable toughness while simulations could be done to optimize spacing to avoid plugging during production. The thickness of ESS could be optimized with consideration of the desired internal diameter of the production tubing to maintain improved production while avoiding collapse. Furthermore, shape memory alloys and polymers have been identified to have a blend of expansivity, toughness, erosion resistance, and SME [76], therefore they could improve the collapse rating of ESS making it pertinent for their responses to collapse, and erosion to be studied. Both prepacked screens and woven or metal mesh screens are easy to plug but withstand erosion. This essentially comes down to material type improvement, but since most of these screens are replaced after a while, the fine line between performance and cost should also be taken into account. Additionally, excessively expensive screens might not be desirable. Overall, performance is observed after use in service, but in order to predict or comprehend performance, one must be aware of the underlying mechanisms. The next section examines the underlying mechanics of screen erosion.

3.2. *Failures due to mechanical erosion*

This section will discuss a review of some of the suggested mechanisms for sand screen erosion. Zhang et al. [77] proposed a mechanism for sand screen erosion. According to their findings, small particles, once they pass through the gravel layer, have an impact on the filtering layer. This impact, driven by turbulence, introduces irregularities and results in collisions with the filtering layer at varying angles and velocities [78]. Such interactions can result in the creation of extrusive lips or depressions and, under certain conditions, may even lead to the development of radial cracks. In the case of substantial impact forces, these cracks can lead to the material being peeled off the filtering layer. They stated that 'the sand screen erosion is a process of a huge number of discrete particles eroding screen at multi-angle in the turbulent regime'. Greene and Moen [79] and Regulacion & Shahreyar [80] have noted that in horizontal gas wells, annular flow is a critical factor contributing to the erosion and failure of sand screens. Similarly, Gjedrem [70] found that high annular velocity tends to cause of extreme screen erosion. However, Gillespie et al. [19] linked early-life screen failures to severe plugging with solids from drilling fluid, a condition that may have arisen during the installation process.

The screen's failure time can be relatively short, influenced by factors such as the flow rate, the extent of screen plugging, and the quantity of fines being transported. The relationship between velocity and erosion rate is evident. Even a slight rise in fluid velocity can have a significant impact on specific erosion. For example, 50 % increase in fluid velocity can lead to a remarkable 170 % increase in

Table 4
Advantages and disadvantages of sand screens , Parlar et al. [76].

Screen type	Advantages	Disadvantages
Wire-wrapped screen	Most difficult to plug	Less resistance to erosion Improper spacing might result in the production of formation sand or plugging
Expandable sand screen (ESS)	Reduced risk of hot spots and blockages	Low collapse rating
Prepacked screen	Can withstand some erosion	Easiest to plug
Woven screen or metal mesh	Can withstand some erosion	Relatively easy to plug

specific erosion [79]. Hamid & Ali [63] proposed that the erosion mechanism is attributed to partial plugging, which occurs when a mixture of coarse sand particles and fine particles is present. Additionally, they noted that partial plugging can occur with or without full annulus packing, depending on the PSD of the gravel. Svela et al. [81] identified two mechanisms for screen erosion: (1) screens becoming plugged with scale or fines, leading to high flow through a limited part of the screen and subsequent erosion and failure; and (2) mobilization of fines and the production of sand/fines associated with water breakthrough, resulting in screen erosion. According to Procyk et al., [71], while screen plugging is expected in typical field conditions, in erosion tests, employing a small, constant-size particle slurry yields more dependable long-term erosion results and enhances test repeatability. Hence, to avoid screen plugging during the test, they sieved the particles to an average diameter of 32 μm. Based on the above information, it can be inferred that plugging can act as a trigger for erosion, as high-velocity spots are likely to occur. However, there is a limitation of studies on plugging-induced erosion of sand screens. Consequently, there is a need to gain a better understanding and conduct examinations of the erosion mechanism in this scenario.

4. Conclusion

This study took a close look at sand screens from different points of view to create a clear background understanding of sand screens and arguments as to why SAS screens are chosen for application in different conditions. It was revealed that the selection and performance of sand screens are mainly based on the particle size distribution which further had specificity for different mechanisms and screen type and the material type which have been observed to be vital in selection due to erosion of screens that is a major basis of screen failure was discussed and suggestions for upscaling to meet changing production demands were made. Furthermore, thorough reviews of works of literature suggested that the rate at which sand is produced relates to the performance of screens based on plugging, as skin effects of screens increase over time due to fines and since limitations have been identified in screens, they can be manipulated to improve their performance in future operations. Screen failure due to erosion is the most common failure cause and studies have discussed them singly or in combination with corrosion, however, erosion in high sand-producing wells are more significant challenges to consider. Premium screens with multiple layers, wire-wrapped screens, basic screens, slotted liners, and pre-packed screens are some of the SAS screens developed for distinct performance purposes, gravel packs are also available with improved production with its own limitations. However, present studies focus on the erosion effects and look towards bettering the materials alongside the techniques and these have led to novelties in ceramics (CSS), ESS, and shape memory material. The life of a screen to a great extent depends on annular flow velocity or turbulence around the annulus of sand screens which clearly explains the relationship between the erosion and velocity.

5. Recommendations

The following are some major recommendations from the critical reviews and findings of this study.

- Table 2 suggested that material types are important in the performance of sand screens and ceramics, metallic alloys and polymers were identified as tested samples with different responses based on temperature and stress. Studies can blend ceramics and metals, polymers and metals, polymers and ceramics, or a mix of the three components by coating, cold working, sintering, and other manufacturing processes to attain specific resistance to sand erosion at the wellbore.
- Materials with shape memory effects can further be investigated to explore their performance and resistance to erosion when used in sand screens.
- Since particle size distribution is a major determinant of the sand control method applied as suggested in Table 1, then coring practice should be encouraged to enable a clear assertion of the PSD at different levels of the reservoir for optimal screen selection.
- Since the design of a sand screen is a function of both the mechanism of screening and material, studies could focus on weak spots like edges, annulus, and surface that get direct contact with sand during production.

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CRediT authorship contribution statement

Abdullah Abduljabbar: Writing – review & editing, Writing – original draft, Resources, Formal analysis, Conceptualization. **Azubuike Amadi:** Writing – review & editing, Writing – original draft, Conceptualization. **Mysara Eissa Mohyaldinn:** Writing – review & editing, Supervision, Funding acquisition, Data curation. **Syahrir Ridha:** Writing – review & editing. **Obai Younis:** Writing – review & editing, Data curation. **Fahd Saeed Alakbari:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data included in article/referenced in article.

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Abbreviations

MWNT	multi-walled carbon nanotubes
PU-SMP	polyurethane shape-memory-polymer
CFRP	carbon fibre-reinforced polymer
ESS	Expandable Sand screens
OHGP	Open hole gravel pack
PSD	Particle size distribution
SAS	Stand-alone screen
SBS + PCL	styrene-butadiene-styrene tri-block copolymer & poly(-caprolactone)
SME	Shape Memory Effect
SMM	Shape Memory Materials
WWS	Wire-wrapped screen
MMS	Metal mesh screen

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