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Journal of Mechanical Working Technology, 10 (1984) 193—208
Elsevier Science Publishers B.V., Amsterdam   Printed in The Netherlands

EFFICIENT OPERATION OF CENTRIFUGAL IMPACT-TREATMENT EQUIPMENT*

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(Received May 20, 1983; accepted June 20, 1983)

Industrial Summary

Whilst other types of capital plant are usually efficiently operated and maintained to ensure consistent results, good performance and cost effectiveness, impact-treatment installations are seldom operated near their full potential. The present paper highlights existing operational weaknesses and addresses itself to explain the major causes and the resulting damaging effects of the inefficient operation of the equipment.

Finally, a number of proposals are offered in order to enable the regaining of the performance standards originally established by the designers and manufacturers.

1. Introduction

Impact-treatment processes involve the bombardment of components with shot or grit particles travelling at high velocity. These processes take numerous forms, the main areas of interest to this study being referred to as shot-peening and its derivatives — blast cleaning and surface preparation which together have applications in the manufacture, improvement and protection of a wide range of components.

Impact-treatment operations have now developed into the category of a machine tool although, with the exception of shot-peening, this has largely gone unrecognised. The result is that centrifugal blast-cleaning equipment is often operated at well below its potential.

The current economic situation emphasises the need for more efficient use of resources. Financial pressures for better productivity are exposing the need for reducing energy, materials and labour costs of traditionally loosely controlled impact-treatment activities. The present paper, however, is concerned only with the effects of maladjustment and wear on energy

*Presented at the First International Conference on Impact Treatment Processes, Cranfield, U.K., September 5—8, 1983.

and material costs. The annual cost of these effects is estimated* at £2.5 millions in the U.K. alone.

This paper is divided into two main parts: the first deals with the causes and effects of inefficient operation and the second with the measures to be taken to regain the performance stipulated by the designers and the machine manufacturers.

It is hoped that directing attention towards the wider spectrum of inefficient operation of impact-treatment plants and offering reasons for such inefficient operation will suggest, to these concerned with the process, guide lines for ensuring maximum economy of operation.

2. Major causes and effects of inefficient operation

In order to illustrate these causes, a simplified centrifugal blast table machine of the type shown in Fig.1 has been selected, as this incorporates all the essential features of typical impact-treatment equipment. In this type of installation it is normal to feed the media by gravity through a feed spout to the core of an impeller, the latter being attached to the blast wheel and enclosed in a fixed casing with a single exit-slot. Rotation of the impeller accelerates the media inside the case and centrifugal forces

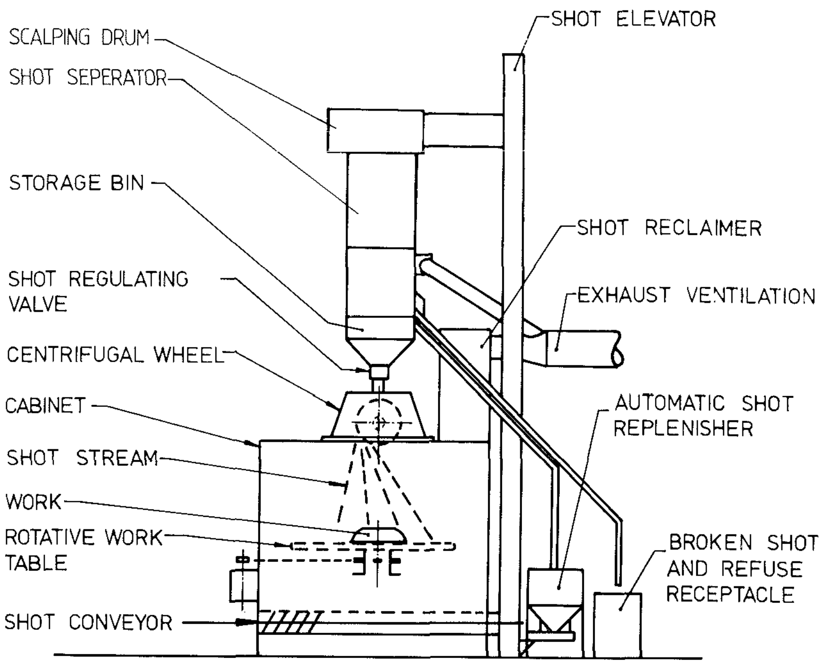

Fig.1. Schematic of a centrifugal peening machine.

*This estimate is based upon the spares costs as experienced by a typical company, extrapolated to account for the scale of the total U.K. blast-cleaning activities.

cause the media to pass out of the exit slot along a tangential path. The media stream is picked up by the rotating vanes and is accelerated to the final exit velocity, as shown in Fig.2.

The wheel is the heart of any centrifugal impact-treatment installation and is the prime factor which determines operating costs and efficiency. For further details of the effects of maladjustment and wear on operating costs and efficiency of blast wheels the reader is advised to see Refs. 1 and 2. The wheel also represents the main area of wear and therefore justifies a closer examination.

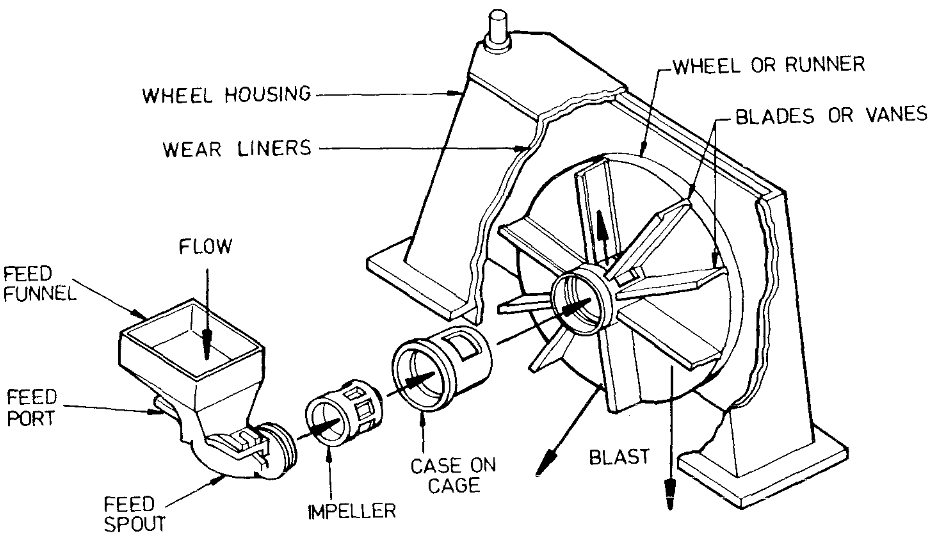

Fig.2. Schematic of a centrifugal blast wheel.

2.1. Wheel assembly

Normal vane-wear and surface instability first appear at the inner end of the vane in small transverse ripples which gradually change after a distance of approximately 50 mm into long scores running parallel to the longitudinal axis of the vane and extending to the outer end, as shown in Fig.3. These ripples are caused by the slight impact occurring as the media particles are picked-up by the inner end of the vane (root) whilst the longitudinal scores are caused by the media sliding along the working surface of the vane as it is rapidly accelerated to an exit velocity in the region of 73 m/s. The wear pattern develops more rapidly at the outer end of the vane owing to the higher speeds involved, and because the outer periphery is usually more exposed to the "ricochetting" media particles inside the blast cabinet. As a result of this, grooves will develop, with occasional deeper pockets which will eventually penetrate the casting if the vane is not replaced.

The wear patterns described above cause the media particles to bounce along the full length of the vane instead of sliding smoothly along it. The

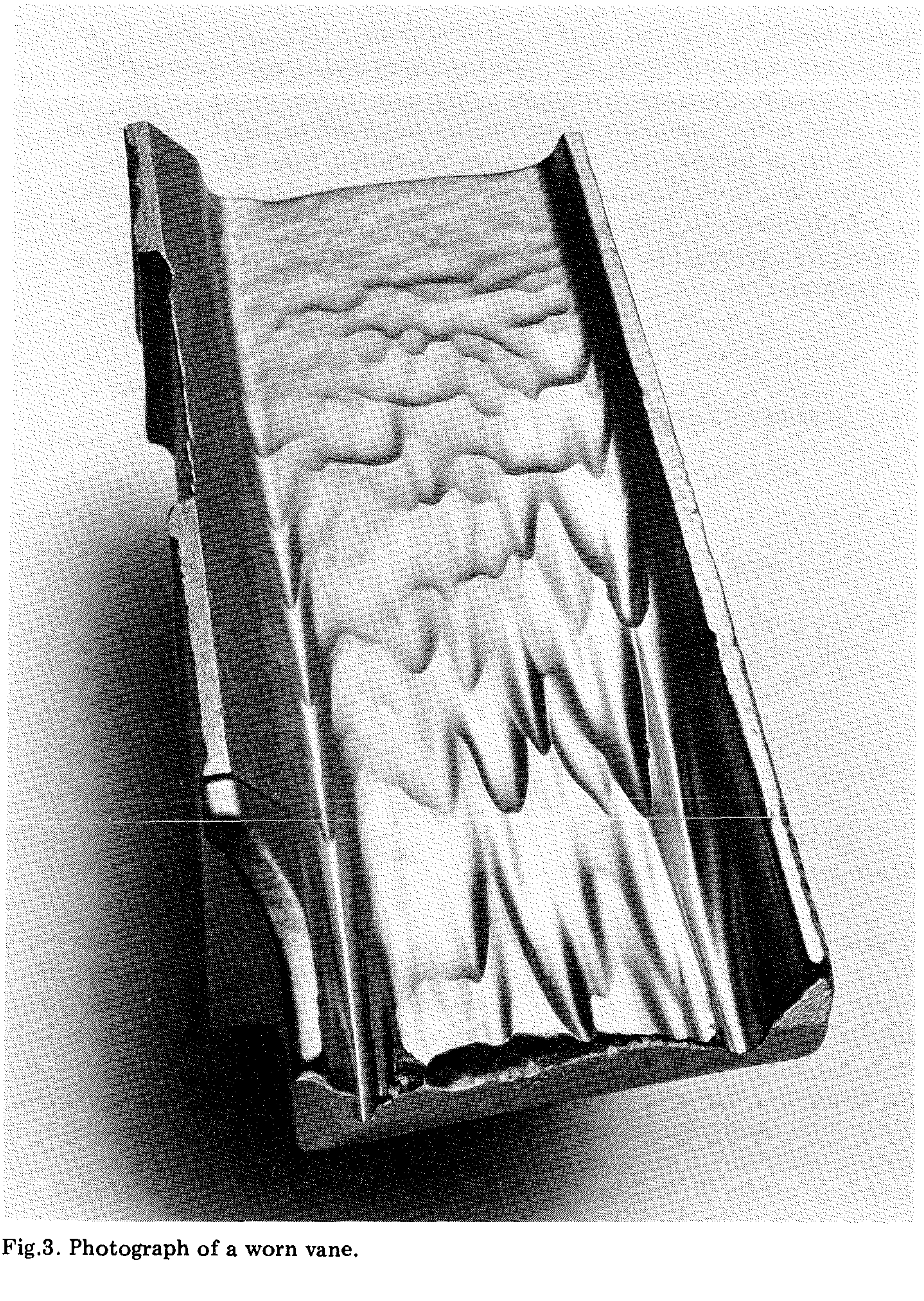

Fig.3. Photograph of a worn vane.

blast pattern accordingly increases in length, particularly at the 'tail' end, resulting in a proportion of the available blast missing the target or workpiece and a reduction in blast intensity in the target area. Perforation of the vanes causes media to be directed anywhere throughout 360° of arc resulting in very high rates of wear on the hood liners and the cabinet wear-plates, and additional unnecessary wear on the remaining sound vanes.

Impellers wear on the leading or driving face of the spacer bars, particularly in the two corners, where notches occur, as depicted by Fig.4. This wear will cause local high concentrations of abrasive in the media stream producing corresponding wear on the inside cylindrical surface and cut-off edge of the impeller case.

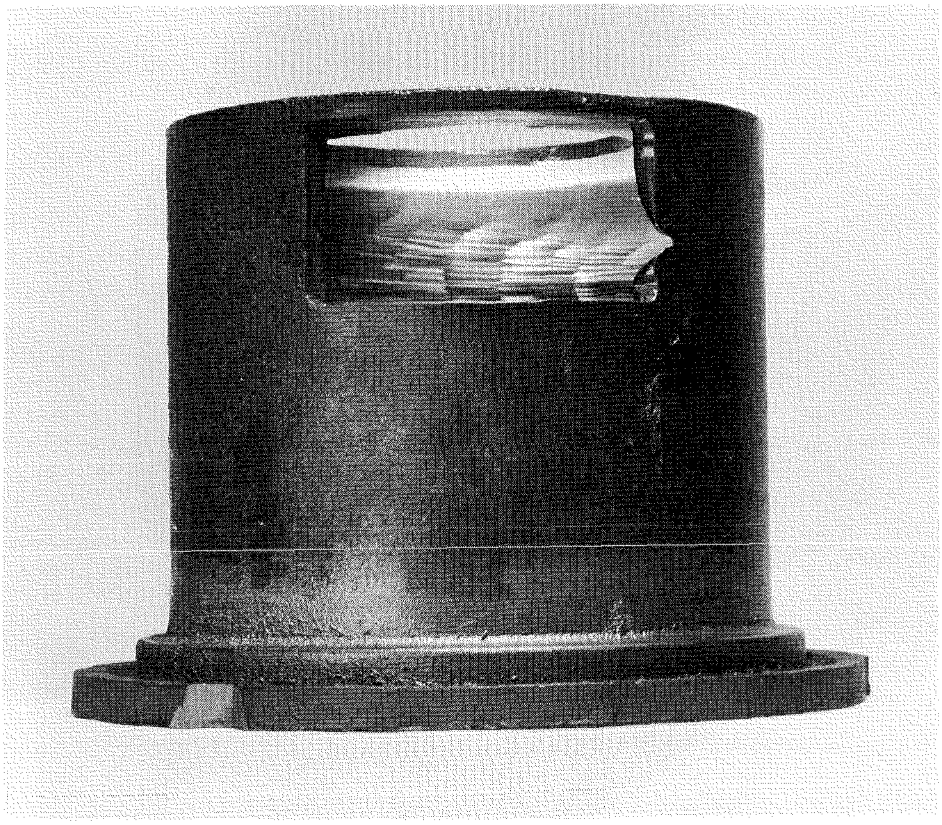

Fig.4. Photograph of a worn impeller.

Any form of eccentricity — whether caused by component inaccuracies, faulty installation or as a result of wear — tends to create an uneven media flow onto the vanes which in turn causes uneven vane wear. One, two or more vanes will wear more rapidly than the remainder creating unbalance in the wheel assembly, thus causing vibration of the latter and excessive noise.

Owing to the enclosed location of the impeller, slow progressive wear is not always obvious and can easily be overlooked or neglected. The ultimate result can be disintegration of the impeller, frequently accompanied by

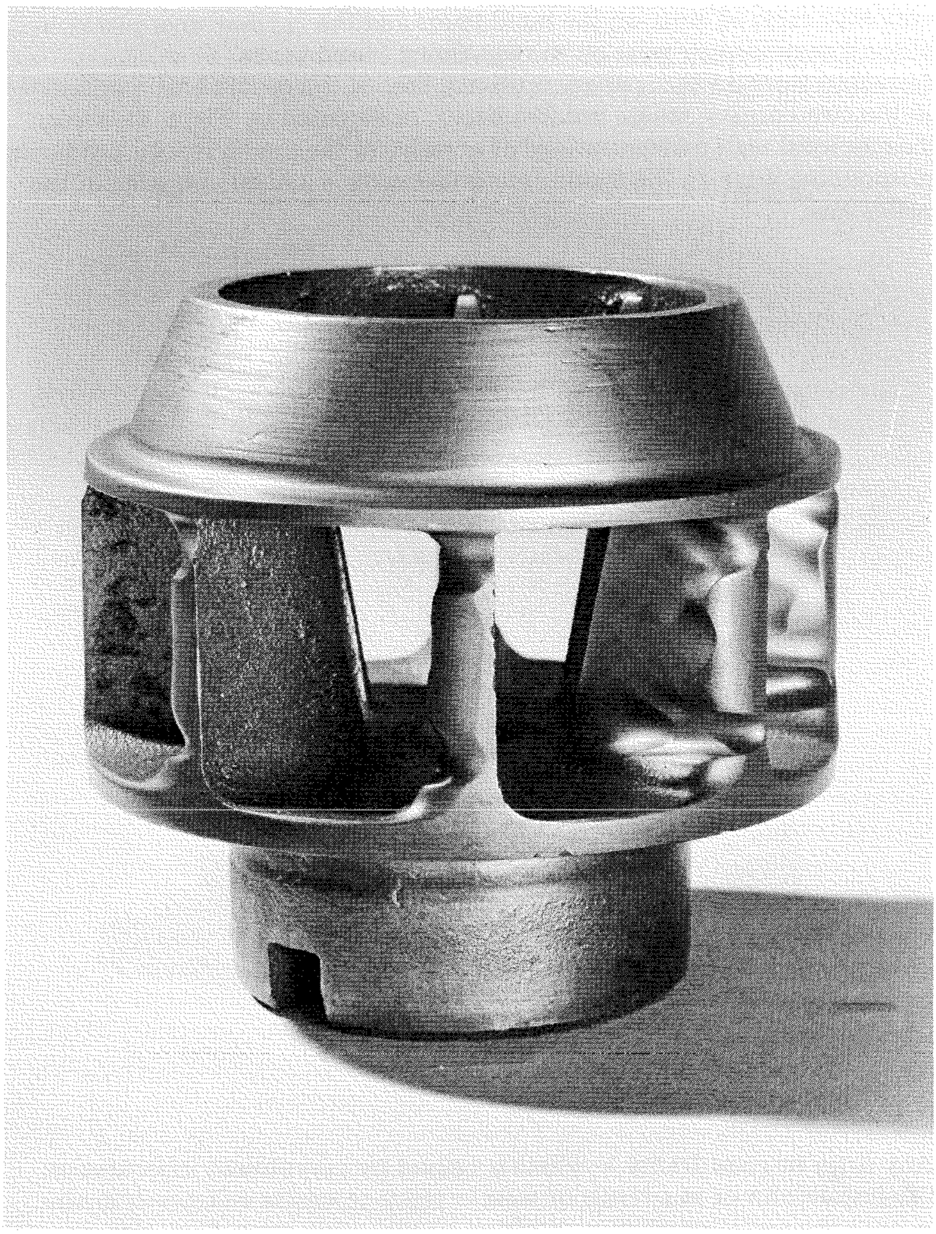

Fig.5. Photograph of a worn impeller case.

destruction of the impeller case and vanes. Impeller case wear can also be difficult to detect unless inspection of the item forms part of a planned maintenance procedure. Wear occurs on the inside peripheral surface of the barrel and on the chamfered cut-off edge of the media discharge opening, frequently in line with the previously mentioned wear points on the impeller. This is illustrated very clearly in Fig.5. If internal barrel wear is allowed to perforate the case, abrasive will be allowed to pass onto the vanes at an incorrect angular position thereby destroying the pre-determined blast pattern and the ability to control it. Further wear could cause the break-up of the cage and vanes.

A relatively small amount of wear on the media exit-slot represents a noticeable angular extension to the designed aperture and also disrupts the smooth transition of abrasive from cage to vane and along the vane face. The overall result is a movement of the complete pattern in the direction of rotation of the wheel, and an increase in the length of the pattern with a corresponding reduction of blast intensity in the target area.

It is worth mentioning that a well designed wheel will outlast many sets of feed parts but will eventually show signs of wear: this is usually greatest towards the outer periphery where velocities are highest and where the wheel is most exposed. Both faces wear, causing thinning of the wheel, and the periphery wears — usually in a series of grooves initiated by irregularities in the rim, i.e. vane slots etc. — reducing the wheel diameter progressively. After prolonged usage, support for the vanes will diminish and an out-of-balance situation will arise.

2.2. Cabinet

Protective cabinet linings deteriorate as a result of steady erosion throughout their use — particularly in areas directly in line with the blast wheel(s) — or occasionally through failure of the fixings through excessive vibration or mis-use exposing the machine structure to the effects of wear. Work aperture seals and door seals also suffer with prolonged use and maltreatment and should be inspected regularly. Lack of attention to the above faults can result in costly repairs and down time and loss of expensive media, and can also present a serious safety hazard.

2.3. Media recirculation system

Screw conveyors and their associated troughs, and vibratory and belt conveyors all deteriorate slowly with use, but the resulting slight reduction in performance is not usually obvious to the user owing to the generous service factors incorporated in the original design. In the majority of cases the media return equipment is below floor level, frequently in an enclosure, and as a result is forgotten until complete failure of one part of the mechanism occurs.

In approximately 4 minutes operation the whole of the media in the machine, which may total 10 tonnes or more, passes through the blast wheels and accumulates in the main media collection hoppers.

The media elevator on impact cleaning machines is usually of the flexible belt and bucket type to eliminate the possibility of mechanical seizure, but as a result of this the drive to the belt assembly is by frictional contact with the head pulley. Belts stretch with use, particularly in the first few hours of operation, and if not corrected will reach the stage where all drive is lost and the media is not taken away from the bottom conveyor.

The fluctuating loads imposed upon the buckets and fixings by the returning media may eventually cause a bucket to detach itself from the belt: this will either jam the elevator completely or restrict the free flow of media, resulting in a similar stoppage to that described above.

2.4. Media cleaning equipment

The returning media is first passed through a rotary screen or scalping drum to remove oversize materials and simultaneously assist in distributing the re-usable media and fines across the width of the separator situated below. To ensure consistent results the scalping drum must be clear of obstructions liable to disrupt the smooth flow of material through the unit.

On some applications, particularly in the foundry, a wire dislodged from the work will find its way into a perforation and cause a minor restriction to the flow. Unfortunately this wire will collect others, creating a 'birdsnest' which will restrict the perforations in the screen, causing the material to bounce instead of travelling smoothly, thus resulting in usable media being rejected down the oversize chute. This is clearly demonstrated in Fig. 6. The fines separator shown in Fig.7 is incorporated to maintain the required grading of media within close limits and to remove unwanted contaminants so that consistent impact treatment is effected on the work.

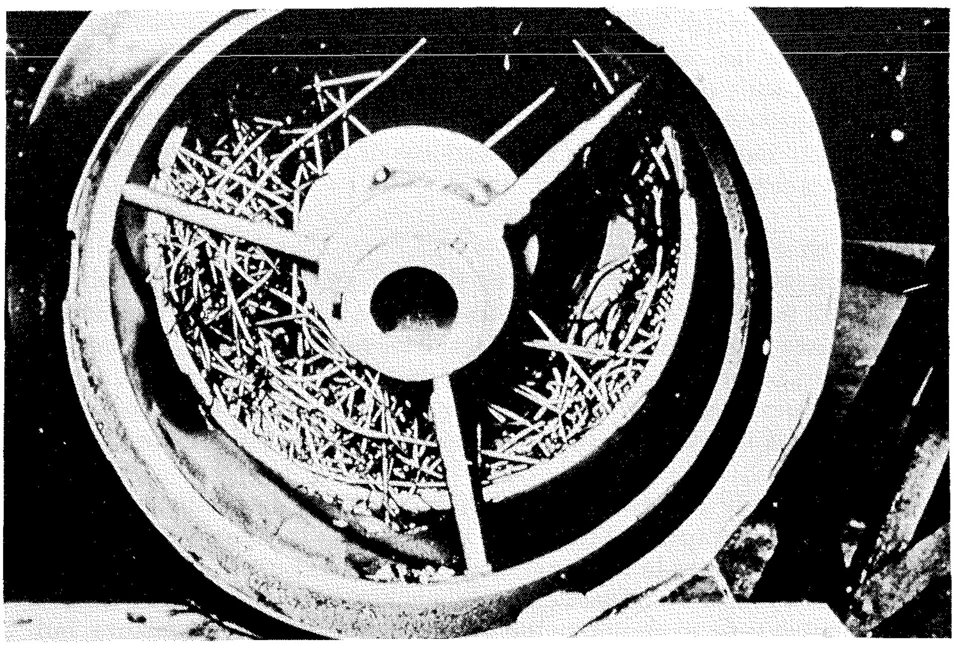

Fig.6. Showing wires obstructing a scalping drum.

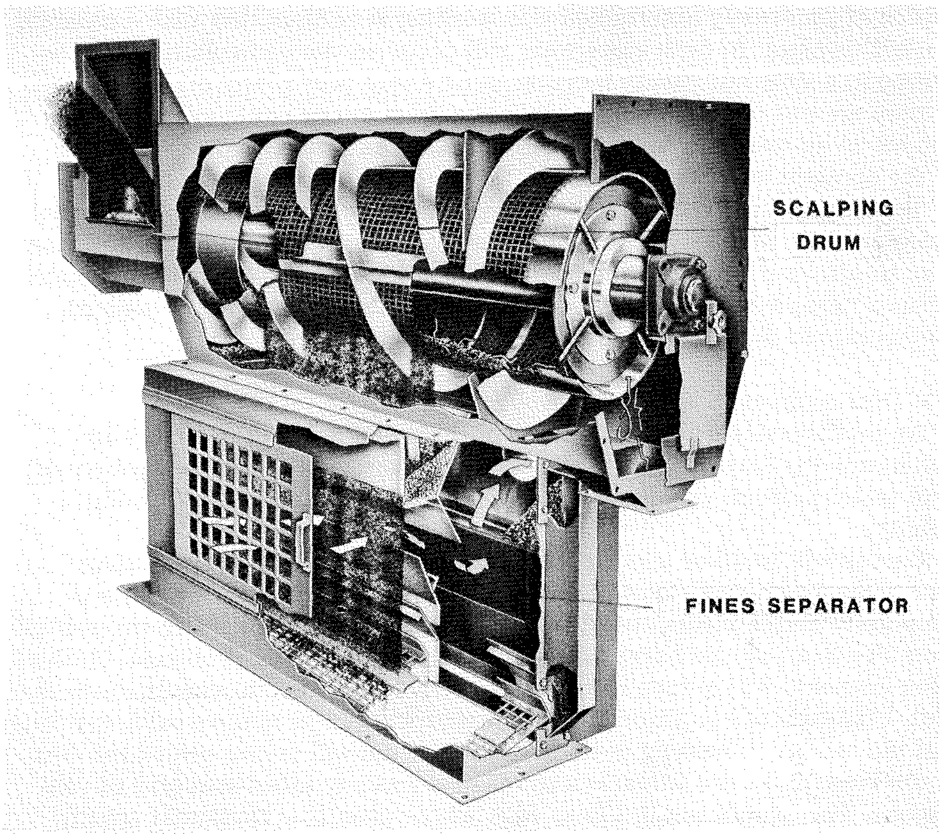

Fig.7. Sectioned view of an abrasive reclaim unit.

An incorrectly adjusted separator will result in either useful abrasive being rejected down the fines chute and lost or alternatively an excessive build up of fines in the re-usable media. The latter can be very important in the foundry where the fines will be sand which is extremely aggressive. Field tests have proven that 1% to 2% sand in metallic cleaning media can increase wear on wheel feed parts and vanes by a factor of 10*. The presence of sand in the re-usable media will also generate excessive dust inside the blast enclosure resulting in cleaned work carrying a coating of dust.

The use of inadequately sized bins for fines and oversize rejects or failure to remove them when full can cause the rejects to build up inside the chutes until the fines settling chamber inside the separator becomes "choked" and the rejects fall over the splitter plate into the 'middlings' chute or re-usable abrasive section.

2.5. Media feed

The Media flow-rate to the blast wheels is controlled by either an adjustable gate — also capable of serving as an 'on/off' valve — or a fixed

*Results of unreported tests carried out in the company of R.H.W.

orifice of previously determined size working in conjunction with a separate 'on/off' control. In both cases wear will occur on the controlling edges, resulting in a slow but steady increase in flow rate over a long period of time. If steps are not taken to control this, the drive motor could eventually be subject to an overload condition. Changes in the media used or variations in the abrasive 'mix' can also affect flow rates in a similar manner.

The most usual method of detecting variations of flow rate on industrial machines is to incorporate an ammeter in the wheel motor circuit. Readings may be affected by other operational problems but in practice the ammeter offers a "simple to understand", robust and reliable indicator. Wheel ammeters should always be maintained in efficient working order.

2.6. Dust collector

An inefficiently maintained dust collector will result in incorrect air volumes being extracted from the blast enclosure and ancilliary equipment, with serious effects on operational efficiency, running costs and product quality.

Excessively worn or leaking filter elements can result in increased airflow rates which will affect the operation of the fines separator and possibly draw usable media out of the blast enclosure. Dust will also be emitted from the clean air discharge stack, causing environmental problems. Choked filter elements will reduce the amount of ventilating air flowing through the unit. Under these conditions, the separator will fail to remove sufficient fines and the residue remaining in the re-usable media will create additional dust in the blast enclosure which is also operating at a reduced standard of ventilation. The overall result will be high wheel wear, low treatment speeds, low product quality and possibly a dusty environment around the machine.

2.7 Work handling equipment

Work handling equipment can take many forms, typical being tumbling drums, mill belts, rotary tables, and various forms of hanger- or roller-conveyor, all of which must be effectively maintained to ensure efficient and safe operation of the installation.

Excessive wear on work table or cabinet floor plates can result in unseen and undetected wear taking place on the abrasive collecting hoppers, scraper pans, and conveyors until perforation of the platework or failure of the mechanical parts occurs. Usually, the first indication of this kind of problem is a steadily increasing demand for media and action should be taken immediately to find and correct the fault. Failure to do so will usually result in substantial "digging-out" of media being necessary when repairs are eventually attempted with the inevitable loss of production time.

Lack of attention to the work conveying system can result in a failure calling for shut down of the installation or secondary damage caused by workpieces falling from the conveyor. The latter case may result in serious damage to one or more blast wheels or to the machine structure. Although manufacturers use very generous safety factors in the design of this type of equipment owing to its self destructive nature, neglect can introduce an unnecessary safety hazard.

2.8 Media

The selection of the optimum type and grade of media and maintenance of the correct "mix" at all times is of prime importance if consistent standards of treatment are to be achieved.

A newly commissioned machine will be loaded with one, two or in some cases, three graded sizes of abrasive in an attempt to simulate a typical operating mix. The particles will degrade with use, the required stablised operating mix being achieved by adjusting the separator, etc. Variation in the mix will cause variations in the abrasive flow-rate and will also affect the treatment of the work owing to the changing number of impingements per unit area and the intensity of those impingements.

Different applications can have totally different media requirements: the following three examples illustrate the point. Peening applications call for consistent particle size within close limits, the particles being truly spherical without voids. Cleanliness is also essential, but this is not usually a problem in peening operations. (For a detailed description of the effect of the use of a defective shot upon the efficiency of the peening the reader is advised to see ref. 3.)

Foundry cleaning operations require particle sizes to be consistent and within size limits. Very small abrasive particles do not assist the cleaning process. Sand contamination must be kept as low as possible, preferably below 0.1% by weight in cleaned abrasive. Mix is of prime importance on descaling applications, the range frequently being from a maximum of 1 mm diameter down to 0.15 mm diameter. The large particles pulverize the scale layer whilst the smaller particles, by virtue of their vast numbers, ensure effective coverage and are also capable of scouring out small cavities, etc. Practical experience shows that any variation in the optimum media specification will result in slower and inferior impact treatment. The basis of a consistent "mix" is established by ensuring that new abrasive is added in small amounts at regular intervals and the required mix is maintained by careful adjustment of the fines separator.

3. Corrective action

Rectification of faults will normally take one or more of the following four forms: (1) replacement of worn components; (2) repair of sub-assemblies; (3) re-adjustment of one or more items of equipment; and (4) simple cleaning. A planned preventative-maintenance programme will ensure that the appropriate measures are taken before total failure occurs.

3.1. Replacement

Wear or damage of vanes, impeller, impeller cases, wheels and hood liners can only be rectified satisfactorily by replacing with a new component. The gradual deterioration in the performance of impact-treatment equipment is not always immediately apparent and the time to replace parts can only be determined by visual inspection and the application of experience.

Figure 3 shows a vane which has reached the end of its useful life and should be replaced before perforation of the casting occurs. Worn vanes should always be replaced as a complete set to avoid out of balance problems.

Should one vane be mechanically damaged in a set which has only been in operation for say, 10% to 20% of the normal useful life, it may be possible to effect a slight economy by replacing only two vanes — the damaged component and the one diametrically opposite — with a new, balanced pair.

Impeller cases with 3 mm or more wear at any point on the discharge lip should be replaced with a new case, set in accordance with the manufacturers instructions. Impellers should be replaced when wear on the leading face of the impeller bars exceeds 1 mm. Excessive wear in the corners of the bars will impair the strength of the casting. Wheels should be replaced if the out-of-balance forces reach unacceptable levels, usually made obvious by vibration and high noise levels from the wheel unit, or if vane retention is jeopardised. Hood liners should be renewed before there is any possibility of perforation by wear.

Rubber curtains and seals will deteriorate with normal wear or physical damage and replacement is usually the only satisfactory repair.

Dust collector elements will eventually wear, perforate or suffer mechanical damage and are virtually impossible to repair. Replacement of all damaged elements is the only satisfactory method of restoring performance to the required standard.

3.2. Repair

Cabinet liners wear unevenly owing to the uneven distribution of blast effect on the enclosure walls. Linings are usually comprised of unit-sized tiles or plates and a satisfactory repair can be made by replacing the worn parts only. In some instances plates or tiles can be moved around between the high wear and low wear zones to reduce replacement costs.

Cabinet floor plates, meshes, scalping drum and classifier screens fall into the same category as cabinet liners where partial replacement can effect a complete repair.

Owing to the large number of individual components involved in a typical mechanical handling system and the nature of the equipment, faults can usually be rectified by repair although this may also require replacement of small parts. Safety aspects are frequently involved in repairs to work handling equipment and consequently there can be no compromise in ensuring 100% integrity of the finished work. Damage to straightforward platework, i.e. cabinets, vestibules, duct, etc. can obviously be effected by patching.

3.3. Adjustment

Within the previously stated acceptable limits of wear the impeller case can be adjusted to re-target a blast pattern which has moved as a result of normal usage. No adjustment can be made to compensate for changes in the length of a blast pattern caused by wear of the impeller, impeller case or vanes.

Wear on abrasive gates resulting in increased abrasive flow rates to the wheels can be corrected by adjusting the gate bucket with the screw provided. Fixed orifices cannot be adjusted for wear and must be replaced.

Airwash fines separators usually incorporate a damper in the duct supplying the ventilating air to facilitate control of the velocity of the cross-draft of air and an adjustable splitter plate to determine the size at which fines are withdrawn from the system. Careful co-ordinated adjustment of these settings enables all contaminants to be removed and the required clean abrasive mix to be maintained within very close limits.

Individual adjustments to the separator settings should be small and carried out in a logical sequence. After each adjustment has been made the re-

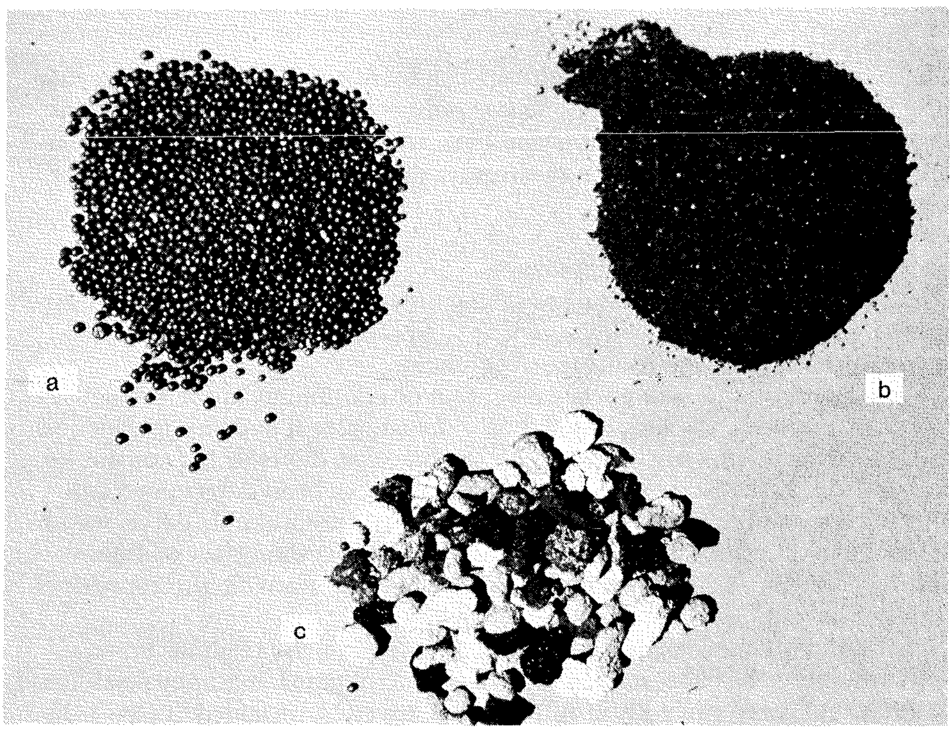

Fig.8. Photograph of rejects from abrasive cleaning equipment.

usable media and rejects should be analysed to determine the effects of the changes on separation efficiency. Adjustments should continue to be made until optimum results are achieved.

Figure 8 illustrates samples of re-usable media, fines and oversize rejects taken from a well adjusted foundry cleaning machine. The points to note regarding each sample are as follows:

Sample (a) comprises re-usable media particles witohin a limited size range (S230) and is free from dust and sand. Sample (b) consists of rejected fines and does not contain any re-usable media or oversize material. Sample (c) comprises oversize rejects and is also free from re-usable media.

Air-control dampers do not usually wear but may require re-setting at infrequent intervals to compensate for changes made in other parts of the system such as the separator described above and particularly after replacement of filter elements. Failure to attend to these points will result in incorrect ventilation of the blast enclosure.

Elevator belts are usually tensioned by manually adjusting two screws supporting the elevator head shaft bearings. Very large elevators are occasionally provided with automatic adjustment on the boot pulley by means of gravity-type tensioning weights or pneumatic rams. The latter system offers advantages when it is necessary to lift the bottom pulley to facilitate shortening of the elevator belt.

3.4. Cleaning

In many cases optimum performance can be restored by merely carrying out a routine cleaning operation. This should cover rotary oversize screens, meshes, feed pipes, rejects chutes and bins. Ductwork should be kept clear and particular attention paid to the regular emptying of the dust collector hoppers.

3.5. Planned preventative maintenance

The most effective method of reducing down time and overall operating costs on impact treatment equipment is to implement a carefully devised planned preventative maintenance programme.

A good programme will cover every item of equipment in the impact-treatment machine, the associated dust exhaust system and any mechanical work-handling equipment upon which the machine depends for continuity of operation. A realistic inspection period will have been determined for every sub-assembly and component based on: (i) the probable deterioration rate and overall useful life of the part concerned; (ii) the effect of failure on the operation of the machine; and (iii) whether or not failure represents a safety hazard.

The timing of the programme should be linked to the readings on an hours run meter incorporated in the main control panel and once established should be followed precisely if full benefits are to be obtained. Table 1 describes a typical planned maintenance programme.

TABLE 1

Machine type

Check items listed at time intervals indicated X.

Times to be taken from wheel hours run meter.

Centrifugal blast wheel unit.

Item	8 Hrs	16 Hrs	40 Hrs	100 Hrs
Vanes	X	X	X	X
Impeller		X	X	X
Impeller case	X	X	X	X
Holder ring			X	X
Wheel			X	X
Deflector			X	X
Spindle (rotate, manually feel and listen for roughness in spindle of wheel)			X	
Spindle lubricate (see instructions)				X
Vee rope tension			X	X
Vee rope (condition)			X	X
Vee rope pulleys			X	X
Abrasive flow (wheel ammeter)	X	X	X	X
Abrasive gate (operation)			X	X
Abrasive gate (wear)			X	X
Hood liners - peripheral		X	X	X
Hood liners - side		X	X	X

4. Conclusions

This paper demonstrated the effects of maladjustment and wear upon the efficient operation of centrifugal impact treatment equipment. A number of proposals have been offered to overcome these effects. In particular, the wheel assembly has been identified as being the main area affecting the running costs and efficiency of operation. An effective planned preventative-maintenance programme will inevitably lower the overall operational costs. As for efficiency, this is controlled mainly by optimum power absorbed by the wheel in transforming the kinetic energy to the appropriate media and applying it to the target area.

The work also demonstrated the preventative measures to be taken to overcome unnecessary wear of components as a result of maladjustment. In the case of foundry applications the correct adjustment of the separator is of paramount importance in order to maintain the contamination of the re-usable abrasive to a minimum level.

Acknowledgements

One of the authors (S.A.M.) acknowledges the support given by the Science and Engineering Research Council under grant GR/B/86408.

References

1 I.A. Mackay, Blast Wheel. In: S.A. Meguid (Ed.), Proc. Conf. on Efficient Operation and Maintenance of Blast Cleaning Equipment, Cranfield, 23rd March 1983, pp. 2—10.
2 R.H. Wright, Effect of Maladjustment and Wear on the Operating Cost and Efficiency. In: S.A. Meguid (Ed.), Proc. Conf. on Efficient Operation and Maintenance of Blast Cleaning Equipment, Cranfield, 23rd March 1983, pp. 111—134.
3 S.A. Meguid and G. Chadwick, Effect of Some Physical Defects Arising During the Manufacture of Commercial Cast-steel shots upon the Efficiency of the Peening Process. Unpublished report, Department of Mechanical Engineering, Cranfield Institute of Technology, 1983.