72 *KSME International Journal, Vol. 14, No. 1, pp. 72~83, 2000*

Engineered Surfaces
Part 1. — A Philosophy of Manufacture

Kenneth. J. Stout*
(University of Huddersfield, UK)

In recent years considerable progress has been made in the characterisation of surface finish in three dimensions, and in the development of protocols which can be used for international standardisation. Although the subject as it has currently developed has much further to go if the process of surface characterisation is to impact on manufacture, control and specification of the manufacturing process itself. Researchers in this important area are beginning to realise that if the subject is to have great impact on manufacturing industries, surface characterisation must be broadened to include measures of surface integrity of the component and in addition be related to the functional demands imposed on the surface. The functional demands being a requirement of the engineering situation in which the components are employed. If these three factors are considered simultaneously, surface characterisation, surface integrity and component function, then a new and important subject is born, the subject of the Engineered Surface. Part 1 of this paper attempts to draw together the elements which go together to create the subject, 'The Engineered Surface'. The paper presents a method by which this important subject can be developed to the benefit of manufacturing industries. The paper also discusses the importance of a co-ordinated approach to the subject and the way that information can be documented to eventually provide a useful atlas of controlling parameters which are essential for a range of material processing industries as they strive to meet the ever more stringent and cost effective requirements of the manufacture.

1. A Philosophy of Manufacture

In recent years considerable progress has been made in the characterisation of surface finish in three dimensions. This has been deemed essential since engineers, conscious of the importance that the surface character has on its functional performance of the component in service, have strived to improve their understanding. One thing has become clear during the evaluation of three dimensional surfaces, although this is an important feature of functional performance many other factors are also equally important. In recent studies, some of which are funded by the EC in relation to setting three dimensional surface characterisation standards, it has become recognised that the functional situation in which surfaces are employed should also be fundamentally investigated (Blunt et al.)

What is it then that makes a functionally successful surface ? It is a combination of the surface topography, the material selection which provides the underlying bulk properties of the material, the properties of the near surface layers, and the control of the manufacturing process by which the final surface is generated.

Traditionally the majority of manufacturing processes which are specified for a wide variety of engineering components, define firstly a selection of appropriate machining techniques by which to generate the surface. This is often achieved by more that one process being undertaken in sequence. The surface that results has in many cases been further modified by subsequent surface treatments to enable them to be more suited to the

---

* Corresponding Author, **E-mail** : k.j.stout@hud.ac.uk
School of Engineering, University of Huddersfield, HDI 3DH, UK. (Manuscript Received September 21, 1999)

function for which they are intended. The purpose of this subsequent treatment, often referred to as surface engineering, is to modify the upper layers of the surface to impart specific properties such as wear resistance or fatigue resistance to improve functional suitability. As a consequence of this time served and widely accepted procedure, the subject of Surface Engineering gained prominence and credibility. Major facilities have been set up in many countries which are now regarded as 'Centre's of Excellence' in this important subject. In addition a highly respected International Journal (Surface Engineering) is directed at reporting the recent techniques and achievements in this field.

The importance and scope of this subject was demonstrated in an international survey of Surface Engineering, particularly directed to surface coatings, which was conducted at the University of Hull (UK), (Matthews et al., 1992). The findings of the report produced as a result of the survey indicated that in the UK alone the expenditure in this area would reach at least £5.5b by the year 2005. Clearly a large section of this expenditure would be related to re-engineering a variety of surfaces for function. An expenditure which might be largely eliminated by engineering the surface appropriately during the final stages of machining or forming if the process parameters had been selected with understanding and care.

But 'surface engineering' has not proved to be the solution to all problems and it is this recognition that has lead to the recent growth in interest of the concept of 'engineering surfaces'.

The concept of 'engineered surfaces' implies that instead of creating a product using some form of machining, forming, casting or fabrication process, then modifying the surface produced to change their properties in an attempt to improve functional performance, it may be preferable and even cheaper in the long term, to begin to understand the consequences of the process of manufacture itself. This might be achieved by being able to carefully control the effects of the process or processes by which the component is produced to induce the desired physical properties of the surface layers. As a consequence of that detailed understanding of the process which produces the final surface. Control of the physical properties of the surface may be possible by specifying the final processing conditions which yield the desired surface topography and corresponding mechanical properties of the surface and sub-surface layers. Thus this better specification would result in a surface highly suited for its intended functional performance.

In other words the properties induced into the surface by the final processing conditions create the 'surface integrity' which in turn is related to the performance that the surface will yield in a functional sense.

This philosophy is not completely new. Whitehouse (1996) showed that the current understanding of the surface generation of most machining processes was minimal, but in his paper he demonstrated that it was feasible to rationally examine the topography of a surface and consequently the physical properties of the surface (its integrity) to begin to understand the consequences of any machining or fabrication process. He also showed that as engineering requirements become more precise and manufacturers are forced to bring down their manufacturing costs it is imperative to understand the implications that the selected manufacturing processes yield. He argued that in most well controlled past and present material processing the workpiece was defined by a small number of simple parameters and from these definitions the component was manufactured. After manufacture the component

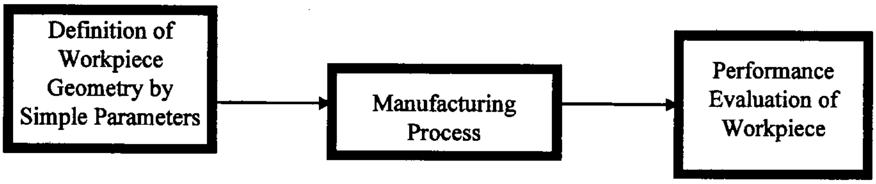

Fig. 1 Past and present manufacturing situation

would be validated for satisfactory performance through either experience or through simple functional tests. For the current manufacturing situation, these steps are diagramatically shown in Fig. 1 below.

A second and probably more scientific approach, is to develop a theoretical basis for the surface interaction and to explore that basis in relation to careful measurements of the component surface. Such a process has been suggested by Whitehouse (1994) in his definitive book on Surface Characterisation. Whitehouse suggested that in an 'enlightened future manufacturing engineering environment', the process of manufacture will require more comprehensive component specification; and as a consequence more complex workpiece geometry descriptions. These will include direction being given on how the component is to be produced by specifying the machining parameters to be employed and in addition, this might lead to the possibly of the need for machine selection to be based on a comprehensive machine diagnostic evaluation. This implies that the integrity of the machine itself, the accuracy of the slideways and bearings, the influences of the motors and the form of surface lubrication or cooling could all have a profound effect on the integrity of the surface produced.

As a consequence the process control parameters are likely in future to include specified limitations on tool wear, cutting speeds and feeds, tool dressing specifications accompanied by the selection and flow rate of the most appropriate coolant to be used during the cutting operation as well as the definition of parameters to be measured to ensure satisfactory compliance to specification. The parameters which are defined are likely to embrace simple geometric and surface roughness considerations, residual stress measurements and surface hardness determination, since these have a direct effect on the component performance (functional performance) in the operational environment. All this will imply that a greater emphasis will need to be given to functional testing of components and products in order for manufacture to conform to international quality standards as well as product reliability and both current and future liability legislation.

surface at 1000 magnification, a micro-hardness traverse, a residual stress profile, high cycle In short the integrity of the surface is a fundamental part of the philosophy of the engineered surface.

There have been some attempts to develop surface integrity standards, one such example is the American National Standard for Surface Integrity B211. 1. The standard stipulates a minimum SI data set outlining the material, its hardness, the process and the process parameters by which it is produced, the surface roughness, the micro cross section of the fatigue data and a reference fatigue value. The standard however is limited in its use of topography measurements and the issues such as directionality and other topography features are not included.

The approach suggested above relates to the need for a well organised programme of investigation into the factors which affect the functional behaviour of production surfaces. Such a programme could be 'ad hoc', or more effectively it could be organised through a number of research or educational establishments who have a specific interest in the outcome of the research to enable them to specify and control the outcomes from a whole range of manufacturing processes. What is important in such an approach is that the data produced during such research is documented and made available to a wide range of interested users and manufacturers.

In the twenty first century we can expect to see industry move to higher precision manufacture for much of its production. For example the expected growth in both ultra precision manufacture and nano technology (Stout, 1997) and the growing requirement for smaller sizes, smaller tolerances and improved compliance in the majority of precision products which will be demanded to meet the more stringent functional requirements of many products.

As a consequence there will be two overwhelming requirements by these precision industries. These are accuracy of manufacture and the suitability of the components and products for its intended function (this later constraint being driven by legislation). Such requirements will imply considerable investment by industry in the understanding of the machining processes and their consequence in the operation of a surface in service.

2. The Complex Inter-Relationships in Producing an Engineered Surface

Before we can make much progress in this broadly based subject — the 'engineered surface'. The complex inter-relationships which make up the engineered surface must be considered. They include ; —

Bulk Material Properties — these have been carefully selected to provide the required component durability using the minimum of material and having the minimum weight. Much progress is currently being made in the automobile industry at the present time through laser welding of dissimilar metals and metals of various thickness. The net outcome of the research into this subject is to provide structures with the required mechanical properties as well as improved crash worthiness. This has been achieved with a significant reduction in total weight and has provided a solution to vehicle body design which is lighter that achieved with aluminium structures with an improvement of mechanical strength.

Surface Properties (either engineered or surface treated) — traditionally surface properties have been 'adjusted' by either heat treatment, to change the material structure, often by inducing phase changes to the surface layers and by chemical modification. This approach is particularly useful in corrosion inhibition. This, as indicated earlier has led to a large growth in surface modifying industries but by its very nature implies that the fabricated surface is not ideal for its intended application. Surface modification by such means is time consuming and costly and is an area of some scrutiny now international competitiveness is of such prime importance.

Surface Operating conditions (including lubricants) — much progress has been made in recent years in the improvement of lubricants. The greatest attention being paid to their wettability (their ability to wet and remain attached to the surface) and their design so that they remain effective as extremely thin films. This has been achieved by research into the effects of the inclusion of special additives to improve the tribological interaction. In recent times though the designers of high performance lubricants have realised that even the most sophisticated lubricant will fail if the surfaces of the tribological components are inadequate and as a consequence much effort is now being directed at the characteristics of the surface which have to be specified in relation to the functional use of the surface and the lubrication employed.

Surface Topography — currently a poorly understood subject in relation the functional use that surfaces are employed for. Depending upon the intended application, the required characteristics of the surface may need to differ, and that difference needs to be understood before the surface is specified. Currently progress is being made on characterisation methods but at this point in time they are more suited to the control of the manufacturing process (a subject which they were originally developed for) rather that the more important area, the characterisation of surface which is related to the function for which they are to be employed. Some early attempts are being made to investigate and understand the requirements for functional surfaces but this requires a co-ordinated effort and much experimentation.

When these four areas are brought together a complete understanding and control of engineered surfaces are possible.

3. Surface Topographical Features and their effect on the Functional Performance of Surfaces

Engineering surfaces can be divided into three groups based on their functionality, translational surfaces, static contact surfaces and non contacting surfaces. In addition to these three groups there is the category where surfaces are required to be specified comprehensively whose sole purpose is to create further topographies on secon-

Table 1 Translational surfaces

Fuction	**Heights**	**Distribution and Shape**	**Slopes and Curvature**	**Lengths and Peak Space**	**Lay**	**Surface Volume Parameters**
Applications						
Bearings	●	●	◗	◗	●	●
Seals	●	●	●	◗	●	●
Sideways	●	●	◗	●	●	●
Mechanisms						
Friction	●	●	●	●	●	●
Wear	●	●	●	●	●	●
Galling	●	◗	●	O	O	●
Fretting	●	●	●	O	O	●

● Much Evidence ◗ Some Evidence O Lillte or Circumstantial Evidence

dary surfaces which then go into functional use.

Translational Surfaces are generally referred to a tribological surfaces and include bearings and slideways, surfaces experiencing friction, wear, galling or fretting. Clearly the amplitude of the roughness, its shape and the separation of the asperities and interconnecting valleys affect the interaction, the retention of the lubricant and affect the leakage of translational seals. The answer to operational performance is to identify the primary tribological interaction, for example the ring/bore interface in internal combustion engine reciprocation, and to ensure that the resultant topographies of the interface are appropriate. In this instance short wave length topography is much more significant than longer frequency waviness which is outside the ring/bore interface interaction length is a significantly less important phenomena. Functional parameters such as valley volumes and valley interconnectability are of significance. A more comprehensive review, based on earlier work by Griffith (1998) in relation to static contact surfaces is presented in Table 1 below. This figure (the first of four) indicates, as Griffith's suggested that there is evidence that the topography was indeed a contributory factor to operational performance. The way in which the information is presented illustrates the current degree of confidence in the correlation between surface finish and function. Clearly some parameters are better descriptors in this respect that are others, and Table 1 presented below is structured in a manner to demonstrate the relative correlation.

Static Contact involving joint stiffness, electrical or thermal contact, adhesion & bonding, fatigue, stress and fracture. This is a contact area related effect and therefore embraces both short wavelength and long wave length effects. Under loading surface asperities deform both elastically and plastically and the net effect is a statistical ensemble of the two deformation mechanisms largely affected by the area of contact of the deformed asperities and the loading applied on them. Clearly asperity heights, their shape and distribution, asperity slopes and curvatures are significant as is likely to be the peak spacing of asperities. The evidence of surface finish relationships in relation to function for the various types of static surface contact is presented in Table 2 below. Much of this figure is again based on the work of Griffith (1998).

Non Contact surface, often related to finishings and include plating, painting, polishing, reflectivity and hygiene. The functionally relevant parameters appear to include asperity heights, their slopes and curvature and asperity separation. For highly reflective surfaces such as optical mirrors and precision lenses the characterisation and counting of 'digs' and 'blemishes' can be

Table 2 Static contact sureaces

Fuction	**Heights**	**Distribution and Shape**	**Slopes and Curvature**	**Lengths and Peak Space**	**Lay**	**Surface Volume Parameters**
Functions						
Joint Stiffness	●	●	◗	◗	◗	◗
Contacts (elec/therm)	●	●	●	●	O	O
Adhesion & Bonding	●	●	◗	◗	◗	●
Mechanisms						
Fatigue	●	◗	O	O	●	●
Stress	●	O	◗	O	●	●
Fracture	●	O	O	O	●	●
Reflectivity	●		●	●	●	●

● Much Evidence ◗ Some Evidence O Little or Circumstantial Evidence

Table 3 Non contact surfaces

Fuction	**Heights**	**Distribution and Shape**	**Slopes and Curvature**	**Lengths and Peak Space**	**Lay**	**Surface Volume Parameters**
Plating	●	◗	◗	◗	O	◗
Painting	●	◗	◗	◗	O	●
Polishing	●	◗	●	●	◗	◗
Reflectivity	●	O	●	●	●	◗
Hygiene	●	◗	◗	O	O	●
Corrosion	●	●	●	O	O	●

● Much Evidence ◗ Some Evidence O Little or Circumstantial Evidence

Table 4 Shaped surface creation

Fuction	**Heights**	**Distribution and Shape**	**Slopes and Curvature**	**Lengths and Peak Space**	**Lay**	**Surface Volume Parameters**
Forming	●	◗	◗	●	◗	●
Dwawing	●	◗	◗	●	O	●
Extrusion	●	◗	◗	O	●	●
Rolling	●	●	◗	◗	●	●

● Much Evidence ◗ Some Evidence O Little or Circumstantial Evidence

significant. Non contact surfaces and magnetic data storage surfaces usually require optical assessment or scanning probe microscopy to ensure that surfaces are not damaged during assessment. The evidence of the relationships between surface finish and function for non contacting surfaces is presented in Table 3 below.

Shaped Surface Creation (which can be considered a hybrid of translational and static contact). These surfaces produce secondary functional surfaces and include the following processes, forming, drawing, extrusion and rolling. The parameters which are relevant to these surfaces include asperity heights, their shape and curvatures as well as their peak spacing. Complex relationship exist when one surface in effect produces a secondary surface. As a consequence it is not just the primary surface functional requirements which must be taken into account, in addition the desired functional attributes of the developed surface is also of significant importance. Evidence of the relationship between surface finish and function is presented in Table 4.

4. Surface Mechanical Features which can Affect the Functional Performance of Surfaces (Surface Integrity)

Surface Hardness which will normally vary to some extent across the surface is partially responsible for the durability of the surface and its resistance to wear, plastic and elastic deformation. If two adjacent surfaces come into contact in a functional sense then their relative harnesses affect their ability to operate as pairs. Often interacting surfaces are required to have differing hardness to limit asperity temperatures and to assist conformity during the running in process.

Residual Stresses;- These are induced during machining or other processing of the surface and can either be tensile or compressive in nature. Essentially residual stresses describe the stress state of the material lattice. Compressive residual stresses are highly desirable in that they act to suppress crack growth as the inter atomic stress acts to blunt any cracks. This has the effect of enhancing the wear and fatigue properties of the surface and improves stress corrosion resistance. Tensile residual stresses on the other hand tend to promote crack growth and are consequently deleterious to the material surface properties.

Plasticity index is a measure of a surface's ability to conform under loading and this will have the affect in contacting surfaces of promoting increased contact between opposed faces. The complimentary effect is to assist the reduction of surface loading by spreading the load over an increased area. If there is substantial lubrication between the surface interface then little or no plastic or elastic deformation will occur as the lubricating fluid will integrate the loading by promoting a fluid pressure profile within the gap between the counter faces.

5. Sub-Surface Features which can Affect the Functional Performance of Surfaces

Sub-surface features which influence functional behaviour of a surface have also been suggested by Griffith (ref. 6.) and these include;-

Untempered martensite(UTM) — is a state which is caused by thermally induced metallurgical transformations in steel and primarily induces tensile residual stress into the surface and sub-surface layers. The formation of untempered martensite has the effect of reducing fatigue life of materials increases the susceptibility to stress corrosion and cracking, reduces wear life. UTM is often induced by thermal energy resulting from high metal removal rates during machining, especially grinding.

Overtempered martensite(OTM) — is found beneath the UTM and is softer than the bulk material due to over tempering. The presence of OTM reduces the bulk material mechanical properties.

Plastic deformation of the surface layers which is usually identified by heavy plastic flowed layers which often appear featureless under the microscope and are termed 'white layers'. Such layers produce compressive residual stress in the surface which assist fatigue life, increase the resistance to corrosion cracking, improve wear properties and surface hardness and assist mechanical properties in general. Machining processes such as honing, light grinding, lapping and forming induce plastic deformation at surfaces and consequentially benefit material properties.

6. Some Examples of Engineered Surfaces

Processes which have been commonly undertaken and are specifically related to the concept of "The Engineered Surface" and whose key process constraint is controlled plastic deformation of the surface layers are described below. Surprisingly these are not in the main new processes. Many of them have been employed for almost a century to improve the integrity of the surface, but their specific understanding is limited and today they are mainly regarded as a 'black art' employed by skill workers and craftsmen who have learned to understand, in general how the process is to be employed and controlled.

Ballising : The process of driving a precision sphere through a machined hole or bore to improve the surface finish, to impart negative residual stresses into that surface to improve surface wear resistance and fatigue resistance. There are a number of applications where such a process is invaluable in increasing, in particular, fatigue life and fatigue resistance, and many of these components are to be found in the aerospace industry and in automobile manufacture.

Swaging : Similar to the Ballising process but where a tapered plug is pulled through a bore to size it and to provide the required negative residual stresses. The advantage of this process is that by carefully selecting the cone angle of the taper the interference between the bore and the swage can be carefully regulated to impart the desired residual stresses. A further advantage of this process is that the dimensional accuracy of the swaged bore is better that that achieved from the ballising process as controlled interference behind the swage is maintained after sizing.

Barrel Finishing : This well established technique is used to improve the finish of a variety of ferrous, non ferrous and plastic components (Wang et al, 1997). Parts slide or float in the medium used so fragile parts can be tumbled as well as heavier sections and the method can be used to improve surface finish without destroying the geometric surface and solid design specifications often required in high technology application. One such application where the method is used to improve performance is found in the manufacture of compressor blades for industrial gas turbines. It is acknowledged that gas turbines, both aero and industrial, require turbo machinery components offering the highest possible efficiency (Niebel et al, 1989) and that gas turbines for mechanical drives require increasingly large power blocks, especially for natural gas pumping, and increasing higher thermal efficiencies (Scrivener, 1991). Sophisticated 3D CFD design methods are used to improve design performance and the advantages gained are matched with continual improvements in manufacturing tolerances. A 1% improvement in tip clearance to blade height in a compressor section will yield an improvement in compressor efficiency in the order of 2% and improvement in surge margin around 5%. Similar gains are made from improved blade finish. Barrel finishing improves the 'as cast' surface from 63 micro inches to 20 micro inches and illustrates the use of a well established technique in high performance gas turbine manufacture.

Shot Peening : This is a further process where the surface properties, in particular the residual stress of the surface layers are modified by impinging the surface with particles, normally lead shot, at relatively high velocity. The kinetic energy imparted by the lead collisions with the surface induces plastic deformation which in turn induces negative residual stresses into upper surface layers, which improves the operational performance of the component. One of the unusual applications where surfaces were shot peened to specifically induce negative residual stresses, was on structural members of the Eiffel Tower during the early nineteen eighties. This process was used to 're-engineer' some of the structural members of the tower rather than be forced to replace them.

Ball and roller Burnishing : These are well used processes which improve the surface finish of the treated component as well as imparting negative residual stresses into the surface layers, this process is mainly used to improve the component' s fatigue resistance. This process, like ballising has been used for many years. Again with this process it is the plastic deformation of the surface layers which induces the compressive residual stress. This process is only used in applications requiring toughened outer layers for its functional application.

Sheet Texturing: This is a relatively new process which has been introduced as part of the final rolling sequence for producing sheet steel and other sheet materials. A defined topography is deliberately imparted onto the finishing rolls which is then transferred to the sheet metal. This process has been introduced to create a defined roughness so that the sheet is able to contain lubricant in the valleys of the micro topography. This is done to reduce friction and avoid the risk of galling during for example, sheet forming. Such texturing can also improve the paintability of sheet materials and as a consequence it produces a surface which has visual improvement. Sheet texturing is primarily conducted in one of two ways. Either EDT texturing or laser texturing of finishing rolls for sheet steel rolling and then transferring the topography to the sheet steel itself by rolling. This process is now widely used in the production of steel sheet for the automotive industry.

There are a number of other processes which fall into the same category as those defined above. They all amount to processes which are introduced to deliberately "engineer the surface" to assist in improving the functional performance of the finished component through controlled plastic deformation. In other words 'engineering surfaces' can be described as the process which the surface is 'functionally finished' for the desired application. This is likely to be a very cost effective objective in modern and future manufacture precision manufacture.

7. Future Approach to the Engineered Surface

For the Engineered Surface to become a broadly understood and scientific approach to surface production, much is needed to be known about the nature of material working and the physical effects that the finishing process has on the surface layers and near surface layers of the material. At present, although there is some understanding of the effects of the processes which work the surface as they are sized and shaped, there is little quantified information to aid the understanding. This is because in the past many manufacturers and research funding bodies have failed to recognise the importance in investing in such understanding.

There are two approaches to examine the problem;-

1. An experimental approach, whereby surfaces are produced under well defined machining or other finishing conditions and those surfaces are then subjected to functional tests, either in a well controlled programme on in 'real life' situations where there is sufficient control of the final product to obtain reliable feed back information. One such programme of this nature has been conducted at Chalmers University in collaboration with Volvo Cars (Rosen and Crafoord, 1992) with their Integrated Surface Modelling software and Avesta Steel with their Surface Database (Blunt, 1998) aimed at specify the production of stainless steel sheet finishes. Both of these systems use processing parameters, metrology information and functional testing to allow the optimal process parameters to be set for given functional outcomes. The systems however require a large investment in data collection from processing, metrology, surface integrity and most importantly functional testing. (the philosophy of these knowledge based systems is shown diagramatically in Fig. 2)

The approach to such a scientific investigation is to determine an experimental rationale to explain the functional behaviour of the 'engineered surface'. This implies that the causes of the separate geometric components which are generated are identified. This may be effectively achieved by a detailed examination of the topography of the surface. The topography provides, for example, the entire 'signature' of the machining operation within the surface asperities. In some circumstances the signature contained in the surface may include information on prefinishing operations as well as the final one.

2. A second approach is to develop analytical models of the surface interactions during machining or fabrication, and through the results of these models, compare the predictions with the surfaces

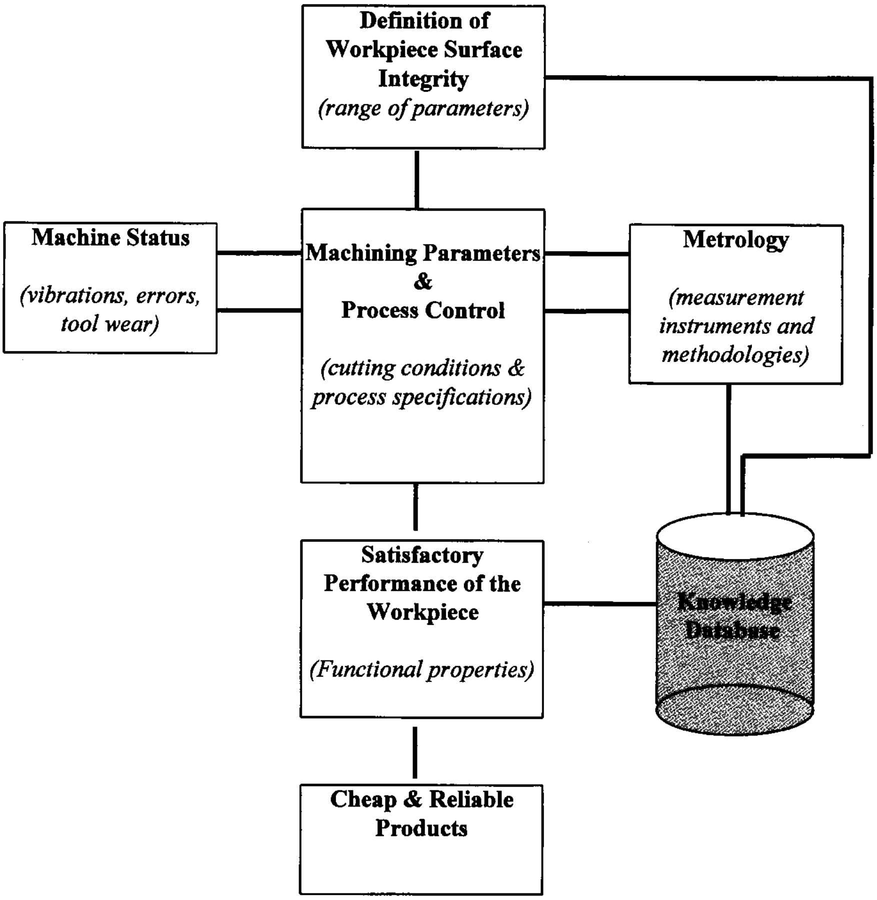

Fig. 2 Modern surface specification and design philosophy

which have been produced. Such a model could take into account information on the influences of the machine tool itself, and this would include the effects of slideways, bearings and the machine stiffness on the resulting surface. Such inputs could contain direct information on the feed rate of the cutting tool, tool wear, coolant type and supply and other processing conditions. Such an analysis could embrace the effects of the material in-homogeneity itself. An illustration of a typical surface analysis and the way in which the signal can be interpreted is presented in Fig. 3.

8. Final Comments

There are a number of other processes which can be investigated to determine the surface conditioning as a result of the specific process used. If all or most of the parameters are investigated which relate to process, it would be possible to produce a comprehensive 'Atlas' of the surfaces produced in association with a range of processes. The development of a range of Atlases would enable the functional process control parameters to be accurately set, which would ensure that the produced topography and its consequential condition of the surface and near surface physical layers, is compatible to the intended function for the surface.

The industrial outcomes of 'engineering the surface' for its intended function include : — Increased product reliability and a reduction of the running — in time of tribological components. Reducing gas 'blow-by' in internal combustion engines to meet current and anticipated future legislation on gas and particle emissions from

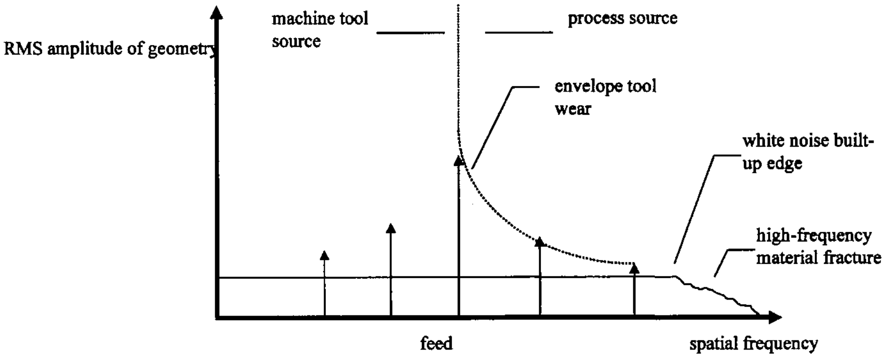

Fig. 3 Fingerprint of a single point cutting prcess. After Whitehouse(1996)

vehicle engines. The use of nanometre sized particles in the production of highly controlled porous materials, for example, to use for aerostatic bearing shells and high precision filters. The structuring of steel sheet and other metallic components for use in the automobile and other industries.

To support the proposals presented in this chapter it is possible to state that there have been in recent times considerable developments in manufacturing processes. Also the development of new materials in recent years and the implications of surface topography combined with surface physics (the engineered surface) of these materials are particularly important in the following areas;-

a. increasing specification and use of multifunctional surfaces to reduce and hopefully running-in and increase both performance and service life of components and products.

b. The production of atomic scale finishes for use in the micro-circuit and micro-chip industries. This will imply energy beam processes and the use of atomic scale abrasives

c. The development and use of new materials, often with closely specified porosity's and physical properties.

d. The development of net shape fabrication processes in an effort to minimise post fabrication machining.

e. The need to develop more economical manufacturing methods. This will occur if the number of process in manufacture are reduced and the requirement to readjust the components after machining, shaping of fabrication is lessened.

It is these trends which will lead to more surfaces being engineered in the final processing of components to meet their long term functional requirements. It is believed that the recent interest in the 'engineered surface' has come to the forefront as greater demands for economy and functionality have been sought. At this time we are experiencing the first faultering steps in engineering surfaces for function. Progress is being made during these studies in the real understanding of processes and their implication. It is a technology which will steadily gain pace and become an essential part of manufacturing research.

References

Blunt, L., "The Development of a Basis for 3D Surface Roughness Standards," First year progress report, Contract No. SMT CT98-2209, Collated and Prepared by the University of Huddersfield, UK.

Blunt, L., 1998, "Avesta Steel-Private Communication."

Griffiths, B. J. 1998, "Surface Integrity, Functional Performance & Standards," *Workshop on Engineered Surfaces*, Cops la Sallette, France.

Matthews, A., Artley, R. J., Holiday, P. and Stevenson, P., 1992, "U. K. Engineering Coatings Industry in 2005," Report for the DTI, Published by the University of Hull.

Niebel, B. W., Draper, A. B. and Wysk, R. A. 1989, *Modern Manufacturing Process Engineering* McGraw Hill, pp. 530~532.

Rosen, B. C. and Crafoord, R., 1992, "Interactive Surface Modelling: Model for a Function — Orientated Expert System for Specification of Surface Properties," *Industrial Metrology*, 2, pp. 107～119.

Scrivener, C. T. J., Connolly, C. F., Cox, J. C. and Dailey, G. M. 1991, "Use of CFD in the Design of Modern Multistage Aero Engine LP Turbine Design. C423/056 I. Mech. E.

Stout, K. J., 1997, "A Review of nano-Technology," *The Korean Journal of Precision Engineering*, Vol. 14, No. 1, pp. 29～51.

Wang, K. H., Blunt, L. and Stout, K. J., 1997, "The 3D Characterisation of the Surface Topography of the Ballising Process," *7th Int. Conf. on Metrology and Properties of Engineering Surfaces*, Gotteborg, Sweden.

Whitehouse, D. J., 1994. "Handbook of Surface Metrology," *Institute of Physics*, ISBN 0-7503-0039-6.

Whitehouse, D. J., 1996, "The Role of Surface Texture, Past, Present and Future," Seminar on Surface Metrology & Surface Analysis, D. T. I., Denmark,