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(54) **FEEDER ELEMENT FOR METAL CASTING**

SPEISERELEMENT ZUM METALLGIESSEN

ÉLÉMENT DE MASSELOTTE POUR FONDERIE DE MÉTAUX

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Description

[0001] The present invention relates to an improved feeder element for use in metal casting operations utilising casting moulds, especially but not exclusively in medium-pressure sand moulding systems.

[0002] In a typical casting process, molten metal is poured into a pre-formed mould cavity which defines the shape of the casting. However, as the metal solidifies it shrinks, resulting in shrinkage cavities which in turn result in unacceptable imperfections in the final casting. This is a well known problem in the casting industry and is addressed by the use of feeder sleeves or risers which are integrated into the mould during mould formation. Each feeder sleeve provides an additional (usually enclosed) volume or cavity which is in communication with the mould cavity, so that molten metal also enters into the feeder sleeve. During solidification, molten metal within the feeder sleeve flows back into the mould cavity to compensate for the shrinkage of the casting. It is important that metal in the feeder sleeve cavity remains molten longer than the metal in the mould cavity, so feeder sleeves are made to be highly insulating or more usually exothermic, so that upon contact with the molten metal additional heat is generated to delay solidification.

[0003] After solidification and removal of the mould material, unwanted residual metal from within the feeder sleeve cavity remains attached to the casting and must be removed. In order to facilitate removal of the residual metal, the feeder sleeve cavity may be tapered towards its base (i.e. the end of the feeder sleeve which will be closest to the mould cavity) in a design commonly referred to as a neck down sleeve. When a sharp blow is applied to the residual metal it separates at the weakest point which will be near to the mould (the process commonly known as "knock off"). A small footprint on the casting is also desirable to allow the positioning of feeder sleeves in areas of the casting where access may be restricted by adjacent features.

[0004] Although feeder sleeves may be applied directly onto the surface of the mould cavity, they are often used in conjunction with a breaker core. A breaker core is simply a disc of refractory material (typically a resin bonded sand core or a ceramic core or a core of feeder sleeve material) with a hole in its centre which sits between the mould cavity and the feeder sleeve. The diameter of the hole through the breaker core is designed to be smaller than the diameter of the interior cavity of the feeder sleeve (which need not necessarily be tapered) so that knock off occurs at the breaker core close to the mould.

[0005] Breaker cores may also be manufactured out of metal. DE 196 42 838 A1 discloses a modified feeding system in which the traditional ceramic breaker core is replaced by a rigid flat annulus and DE 201 12 425 U1 discloses a modified feeding system utilising a rigid "hat-shaped" annulus.

[0006] Casting moulds are commonly formed using a moulding pattern which defines the mould cavity. Pins are provided on the pattern plate at predetermined locations as mounting points for the feeder sleeves. Once the required sleeves are mounted on the pattern plate, the mould is formed by pouring moulding sand onto the pattern plate and around the feeder sleeves until the feeder sleeves are covered and the mould box is filled. The mould must have sufficient strength to resist erosion during the pouring of molten metal, to withstand the ferrostatic pressure exerted on the mould when full and to resist the expansion/compression forces when the metal solidifies.

[0007] Moulding sand can be classified into two main categories. Chemical bonded (based on either organic or inorganic binders) or clay-bonded. Chemically bonded moulding binders are typically self-hardening systems where a binder and a chemical hardener are mixed with the sand and the binder and hardener start to react immediately, but sufficiently slowly enough to allow the sand to be shaped around the pattern plate and then allowed to harden enough for removal and casting.

[0008] Clay-bonded moulding uses clay and water as the binder and can be used in the "green" or undried state and is commonly referred to as greensand. Greensand mixtures do not flow readily or move easily under compression forces alone and therefore to compact the greensand around the pattern and give the mould sufficient strength properties as detailed previously, a variety of combinations of jolting, vibrating, squeezing and ramming are applied to produce uniform strength moulds at high productivity. The sand is typically compressed (compacted) at high pressure, usually using a hydraulic ram (the process being referred to as "ramming up"). With increasing casting complexity and productivity requirements, there is a need for more dimensionally stable moulds and the tendency is towards higher ramming pressures which can result in breakage of the feeder sleeve and/or breaker core when present, especially if the breaker core or the feeder sleeve is in direct contact with the pattern plate prior to ram up.

[0009] The above problem is partly alleviated by the use of spring pins. The feeder sleeve and optional locator core (similar in composition and overall dimensions to breaker cores) is initially spaced from the pattern plate and moves towards the pattern plate on ram up. The spring pin and feeder sleeve may be designed such that after ramming, the final position of the sleeve is such that it is not in direct contact with the pattern plate and may be typically 5 to 25mm distant from the pattern surface. The knock off point is often unpredictable because it is dependent upon the dimensions and profile of the base of the spring pins and therefore results in additional cleaning costs. The solution offered in EP-A-1184104 is a two-part feeder sleeve. Under compression during mould formation, one mould (sleeve) part telescopes into the other. One of the mould (sleeve) parts is always in contact with the pattern plate and there is no requirement for a spring pin. However, there are problems associated with the telescoping arrangement of EP-A-1184104. For example, due to the telescoping action, the volume of the feeder sleeve after moulding is variable and dependent on a range of factors including moulding machine pressure, casting geometry and sand properties. This unpredictability can have a detrimental effect on feed performance. In addition, the arrangement is not ideally suited where exothermic sleeves are required. When exothermic sleeves are used, direct contact of exothermic material with the casting surface is undesirable and can result in poor surface finish, localised contamination of the casting surface and even sub-surface gas defects.

[0010] Yet a further disadvantage of the telescoping arrangement of EP-A-1184104 arises from the tabs or flanges which are required to maintain the initial spacing of the two mould (sleeve) parts. During moulding, these small tabs break off (thereby permitting the telescoping action to take place) and simply fall into the moulding sand. Over a period of time, these pieces will build up in the moulding sand. The problem is particularly acute when the pieces are made from exothermic material. Moisture from the sand can potentially react with the exothermic material (e.g. metallic aluminium) creating the potential for small explosive defects.

[0011] An attempt to mitigate the effect of sleeve breakage is made in DE 201 12 425 U1 by providing the mounting surface that bears the weight of the sleeve with a pair of spaced apart lips that with the mounting surface form a channel or groove within which the sleeve sits. The inner lip prevents broken pieces of the sleeve falling into the mould and the outer lip prevents broken pieces from falling into the moulding sand.

[0012] WO2005/051568 discloses a feeder element (a collapsible breaker core) that is especially useful in high-pressure sand moulding systems. The feeder element has a first end for mounting on a mould pattern, an opposite second end for receiving a feeder sleeve and a bore between the first and second ends defined by a stepped sidewall. The stepped sidewall is designed to deform irreversibly under a predetermined load (corresponding to the crush strength). The feeder element offers numerous advantages over traditional breaker cores including:-

(i) a smaller feeder element contact area (aperture to the casting);
(ii) a small footprint (external profile contact) on the casting surface;
(iii) reduced likelihood of feeder sleeve breakage under high pressures during mould formation; and
(iv) consistent knock off with significantly reduced cleaning requirements.

[0013] The feeder element of WO2005/051568 is exemplified in a high-pressure sand moulding system. The high ramming pressures involved necessitate the use of high strength (and high cost) feeder sleeves. This high strength is achieved by a combination of the design of the feeder sleeve (i.e. shape, thickness etc.) and the material (i.e. refractory materials, binder type and addition, manufacturing process etc.). The examples demonstrate the use of the feeder element with a FEEDEX HD-VS159 feeder sleeve, which is designed to be pressure resistant (i.e. high strength) and for spot feeding (high density, highly exothermic, thick walled, not high volume feed demand). The feeder sleeve is secured to the feeder element via a mounting surface which bears the weight of the feeder sleeve and which is perpendicular to the bore axis. For medium pressure moulding there is the potential opportunity of using lower strength sleeves i.e. different designs (shapes and wall thicknesses etc.) and/or different composition (i.e. lower strength). Irrespective of the sleeve design and composition, in use there would still be the issues associated with knock off from the casting (variability and size of footprint on the casting) and need for good sand compaction beneath the feeder element. If the feeder element of WO2005/051568 were to be employed in medium-pressure moulding lines it would be necessary to design the element so that it collapses sufficiently at the lower moulding pressure (as compared to high pressure moulding) i.e. to have a lower initial crush strength. It would also be highly advantageous to use lower strength feeder sleeves (typically lower density sleeves), which would allow for a greater range of sleeve designs and compositions to be used successfully and optimally for a greater range of casting types and correspondingly lower cost feeder sleeves. However, when this was attempted the inventors surprisingly discovered that the feeder sleeve suffered damage and breakages on moulding which if used for casting would have resulted in the casting suffering from defects.

[0014] It is an object of the present invention in a first aspect to provide an improved feeder element which can be used in a cast moulding operation. In particular, it is an object of the present invention in its first aspect to extend the utility of collapsible feeder elements into medium pressure moulding systems while allowing the use of relatively weak feeder sleeves without introducing casting defects.

[0015] According to a first aspect of the present invention, there is provided a feeder element for use in metal casting, said feeder element comprising:

(i) a first end for mounting on a mould pattern;
(ii) an opposite second end for receiving a feeder sleeve; and
(iii) a bore between the first and second ends defined by a stepped sidewall;

said feeder element being compressible in use whereby to reduce the distance between the first and second ends, wherein the stepped sidewall has a first sidewall region defining the second end of the element and a mounting surface for a feeder sleeve in use, said first sidewall region being inclined to the bore axis by less than 90° and a second sidewall region contiguous with the first sidewall region, said second sidewall region being parallel to or inclined to the bore axis at a different angle to the first sidewall region whereby to define a step in the sidewall.

[0016] The feeder element may comprise additional sidewall regions, whereby multiple steps in the sidewall are defined, in which case at least one of the additional sidewall regions is preferably inclined at a greater angle to the axis than the first sidewall region.

[0017] It will be noted upon reading WO2005/0515 that, although the orientation of the sidewall region defining the mounting surface for the feeder sleeve and bearing the weight of the feeder sleeve is not particularly limited, it is said to be preferably perpendicular to the bore axis as is shown in all of the examples. The only significance placed on the orientation of this surface is that the perpendicular arrangement is the most convenient for mounting the sleeve.

[0018] Preferably the first sidewall region is inclined to the bore axis at an angle of between 5 and 85°, more preferably at an angle of between 15 and 80°, even more preferably at an angle of between 25° and 75°, and most preferably at an angle of between 30° and 70°. For example, the first sidewall region may be inclined to the bore axis at an angle of 60°.

[0019] It will be understood that the amount of compression and the force required to induce compression will be influenced by a number of factors including the material of manufacture of the feeder element and the shape and thickness of the sidewall. It will be equally understood that individual feeder elements will be designed according to the intended application, the anticipated pressures involved and the feeder size requirements.

[0020] Preferably, the initial crush strength (i.e. the force required to initiate compression and irreversibly deform the feeder element over and above the natural flexibility that it has in its unused and uncrushed state) is no more than 5000 N, and more preferably no more than 3000 N. If the initial crush strength is too high, then moulding pressure may cause the feeder sleeve to fail before compression is initiated. Preferably, the initial crush strength is at least 250 N. If the crush strength is too low, then compression of the element may be initiated accidentally, for example if a plurality of elements is stacked for storage or during transport.

[0021] The feeder element of the present invention may be regarded as a collapsible breaker core as this term suitably describes some of the functions of the element in use. Traditionally, breaker cores comprise resin bonded sand or are a ceramic material or a core of feeder sleeve material. However, the feeder element of the current invention can be manufactured from a variety of other suitable materials including metal. In certain configurations it may be more appropriate to consider the feeder element to be a feeder neck.

[0022] As used herein, the term "compressible" is used in its broadest sense and is intended only to convey that the length of the feeder element between its first and second ends is shorter after compression than before compression. Preferably, said compression is non-reversible i.e. after removal of the compression inducing force the feeder element does not revert to its original shape.

[0023] In a particularly preferred embodiment, the stepped sidewall of the feeder element comprises a first series of sidewall regions (said series having at least one member) in the form of rings (which are not necessarily planar) of increasing diameter (when said series has more than one member) interconnected and integrally formed with a second series of sidewall regions (said second series having at least one member). Preferably, the sidewall regions are of substantially uniform thickness, so that the diameter of the bore of the feeder element increases from the first end to the second end of the feeder element. Conveniently, the second series of sidewall regions are cylindrical (i.e. parallel to the bore axis), although they may be frustoconical (i.e. inclined to the bore axis). Both series of sidewall regions may be of non-circular shape (e.g. oval, square, rectangular, or star shaped). The second sidewall region constitutes the sidewall region of the second series closest to the second end of the feeder element.

[0024] The compression behaviour of the feeder element can be altered by adjusting the dimensions of each sidewall region. In one embodiment, all of the first series of sidewall regions have the same length and all of the second series of sidewall regions have the same length (which may be the same as or different from the first series of sidewall regions and which may be the same as or different from the first sidewall region). In a preferred embodiment however, the length of the first series of sidewall regions and/or the second series of sidewall regions incrementally increases towards the first end of the feeder element.

[0025] The feeder element may be defined by the first sidewall region and one each of the first and second series of sidewall regions. However, the feeder element may have as many as six or more of each of the first and the second series of sidewall regions. In a particularly preferred embodiment, four of the first series and five of the second series are provided.

[0026] Preferably, the thickness of the sidewall regions is from about 4 to 24%, preferably from about 6 to 20%, more preferably from about 8 to 16% of the distance between the inner and outer diameters of the first sidewall regions (i.e. the annular thickness in the case of planar rings (annuli)).

[0027] Preferably, the distance between the inner and outer diameters of the first series of sidewall regions is 4 to 10 mm and most preferably 5 to 7.5 mm. Preferably, the thickness of the sidewall regions is 0.2 to 1.5 mm and most preferably 0.3 to 1.2 mm. The ideal thickness of the sidewall regions will vary from element to element and be influenced by the size, shape and material of the feeder element, and by the process used for its manufacture.

[0028] In a convenient embodiment, only an edge contact is formed between the feeder element and casting, the first end (base) of the feeder element being defined by a sidewall region of the first or second series which is non-perpendicular to the bore axis. It will be appreciated from the foregoing discussion that such an arrangement is advantageous in minimising the footprint and contact area of the feeder element. In such embodiments, the sidewall region which defines the first end of the feeder element may have a different length and/or orientation to the other sidewall regions of that series. For example, the sidewall region defining the base may be inclined to the bore axis at an angle of 5 to 30°, preferably 5 to 15°. Preferably, the free edge of the sidewall region defining the first end of the feeder element has an inwardly directed annular flange or bead.

[0029] It will be understood from the foregoing discussion that the feeder element is intended to be used in conjunction with a feeder sleeve. Thus, the invention provides in a second aspect a feeder system for metal casting comprising a feeder element in accordance with the first aspect and a feeder sleeve secured thereto.

[0030] A standard feeder sleeve has an annular base for mounting onto a breaker core (collapsible or otherwise). In the feeder system of the second aspect the base of the feeder sleeve is profiled at the same angle as the first sidewall region of the feeder element.

[0031] The nature of the feeder sleeve is not particularly limited and it may be for example insulating, exothermic or a combination of both. Neither is its mode of manufacture particularly limited, it may be manufactured for example using either the slurry or core-shot method. Typically a feeder sleeve is made from a mixture of refractory fillers (e.g. fibres, hollow microspheres and/or particulate materials) and binders. An exothermic sleeve further requires a fuel (usually aluminium or aluminium alloy) and usually initiators/sensitisers. Suitable feeder sleeves include for example those sold by Foseco under the trade name KALMIN, KALMINEX or FEEDEX. Feeder sleeves are available in a number of shapes including closed and open cylinders, ovals, neckdowns and domes. Preferably the feeder element is used in conjunction with any conventional insert sleeve design which consists of a closed (capped) sleeve that may be flat topped, domed, flat topped dome, or any other insert sleeve design. The feeder sleeve may be conveniently secured to the feeder element by adhesive but may also be push fit or have the sleeve moulded around part of the feeder element. Preferably the feeder sleeve is adhered to the feeder element.

[0032] The invention allows the use of lower strength sleeves to be used down to a value of 3.5N. Preferably, the sleeve strength is at least 5kN. Preferably, the sleeve strength is less than 20kN. For ease of comparison the strength of a feeder sleeve is defined as the compressive strength of a 50x50mm cylindrical test body made from the feeder sleeve material. A 201/70 EM compressive testing machine (Form & Test Seidner, Germany) is used and operated in accordance with the manufacturer's instructions. The test body is placed centrally on the lower of the steel plates and loaded to destruction as the lower plate is moved towards the upper plate at a rate of 20mm/minute. The effective strength of the feeder sleeve will not only be dependent upon the exact composition, binder used and manufacturing method, but also on the size and design of the sleeve, which is illustrated by the fact that the strength of a test body is usually higher than that measured for a standard flat topped 6/9K sleeve. The potential availability of a greater range of sleeve compositions and designs that can be used together with the invention enables the most appropriate (technically and economically) sleeve to be specified for each individual casting, which is not possible with the existing prior art.

[0033] Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings in which:-

Figure 1 is a cross section of a test piece containing features of the feeder element in accordance with invention.
Figures 2a and 2b are a cross section and a top view respectively of a known feeder element.
Figure 3a is a known VSK feeder sleeve design.
Figure 3b is a known 6/9K feeder sleeve design.
Figure 3c is a flat topped dome feeder sleeve design.
Figure 4 is a cross section of another known feeder element.
Figures 5a to 5c are computer simulations of the known feeder element of Figure 4 in use.
Figure 6 is a cross section of a feeder element in accordance with the invention.
Figures 7a and 7b are computer simulations of the feeder element of figure 6 in use.
Figure 8 is a cross section of another feeder element in accordance with the invention.
Figure 9 is a flat topped dome feeder sleeve with modified base together with a feeder element in accordance with the invention.
Figure 10a is a plot of force applied against displacement for a KALMINEX 2000ZP 6/9K feeder sleeve under compression
Figures 10b to 10i are plots of force applied against displacement for the test pieces of Figure 1 together with a KALMINEX 2000ZP 6/9K feeder sleeve with varying angle α.

METHODOLOGY

[0034] In the subsequent examples standard feeder systems comprising standard feeder elements with standard feeder sleeves were tested as well as feeder systems in accordance with the present invention. Both the standard and inventive feeder elements are manufactured by pressing sheet steel. The profiling of the base of the inventive feeder sleeves was achieved either by manufacturing the sleeves with the profile already in place (flat topped dome shaped sleeves) or by the use of abrasive paper on standard sleeves (6/9K shaped sleeves). When manufacturing the profiled 6/9K shaped feeder sleeves commercially it will be understood that it would be more practical to produce the feeder sleeves with the profile already in place.

Moulding Test

[0035] Testing was conducted on a commercial Herman moulding machine using a clay-bonded greensand system. A wooden pattern plate was bolted to a steel plate. Four feeder elements and corresponding feeder sleeves were then mounted onto the pattern plate using locating pins, spaced 150 mm and 114mm from the centre lines of the pattern plate. A moulding flask was placed on the pattern plate to give a mould of approximate dimensions 576mm x 432mm x 192 mm (length x width x height). Sand was added to the flask such that its level was approximately 50mm above the height of the flask. The weight of sand was approximately 112 kg. A 576 x 432mm ram plate was positioned 144mm above the height of the flask (approximately 94mm above the surface of the non-compressed sand) and the mould compressed by downward movement of the ram plate to the prescribed pressure, taking between 3 and 6 seconds to compact the sand to the level of the moulding flask. The mould was then excavated and the condition of the feeder elements and feeder sleeves was observed.

Compression Test

[0036] Feeder element test pieces and feeder sleeves were tested by sitting them between the two parallel plates of a Hounsfield compression strength tester.

[0037] The bottom plate was fixed, whereas the top plate traversed downwards via a mechanical screw thread mechanism at a constant rate of 30mm per minute and graphs of force applied against plate displacement were plotted.

[0038] The feeding element test pieces that were compression tested had the basic configuration shown in Figure 1. Briefly, the feeder element test piece 10 consists of a circular base 12 (of diameter D) with a cylindrical sidewall region 14 (of height h) extending upwardly therefrom. Contiguous with the cylindrical sidewall region 14 is an outwardly tapering sidewall region 16 (with a maximum diameter d) which is inclined toward the cylindrical sidewall region 14 by an angle α. The tapering sidewall region 16 serves as a mounting surface for a feeder sleeve in use. It will be noted that these test pieces used for compression testing are not provided with an opening in the base since they will not be used for casting.

[0039] Various feeder elements were prepared where α = 90° (standard), 80°, 70°, 60°, 50°, 40°, 30° or 20°. The test pieces were manufactured from mild steel with a thickness of 0.5mm. In the case of the standard feeder element test piece (α = 90°) D was 53.5mm, h was 7.5mm and d was 80.0mm. The test pieces were designed such that the height (h) of the cylindrical sidewall region 14, the maximum diameter (d) of the outwardly tapering sidewall region 16 and the area of the mounting surface provided by the first sidewall region 16 remained constant whilst α was varied (i.e. as α decreases, the diameter (D) of the circular base 12 increases). The feeder elements were tested with a KALMINEX 2000ZP 6/9K exothermic feeder sleeve as supplied by Foseco having a density of 0.55-0.65 g/cm^2 and a compression strength of the order 4kN.

COMPARATIVE EXAMPLE 1 - Moulding Test

[0040] A feeder element (a metal collapsible breaker core sold under the nomenclature MH/33 as described in WO2005/051568 and shown in Figures 2a and 2b) was tested in combination with the following feeder sleeves listed in Table 1:

Table 1

	FEEDER HD	KALMINEX 95	KALMINEX 2000XP	KALMINEX 2000XP
Shape	VSK (thick walled mini-sleeve as shown in figure 3a)	6/9K (parallel conical capped insert sleeve with Williams wedge as shown in figure 3b)	6/9K (parallel conical capped insert sleeve with Williams wedge as shown in figure 3b)	Flat topped dome (flat-topped closed dome sleeve with variable wall section as shown in figure 3c)
Manufacturing Process	Core shot	Slurry formed	Core shot	Core shot
Density (gcm^{-3})	1.35-1.45	0.85-0.95	0.55-0.65	0.55-0.65
Strength (kN)[a]	High (>25)	Medium (10-11)	Medium (11-12)	Medium (11-12)
Strength (kN)[b]	n/a	Medium (8-9)	Medium (9-10)	n/a
a) strength of standard cylindrical test body b) strength of actual 6/9K sleeve				

[0041] The sleeve formulations vary according to the required product properties, however, all have the general formulation: 20-25% aluminium fuel; 10-20% oxidants and sensitisers; 5-10% organic binders; and 35-55 % refractory fillers. The type of refractory fillers used has the most direct influence on both density and strength of the sleeves.

[0042] Referring to Figures 2a and 2b, the feeder element 20 comprises a first end (base) 22 for mounting on a mould pattern; an opposite second end (top) 24 for receiving a feeder sleeve; and a bore 26 between the first and second ends 22, 24 defined by a stepped sidewall 28. The second end 24 of the feeder element 20 is defined by a first sidewall region 25, said first sidewall region 25 being perpendicular to the bore axis A. A second sidewall region 30 is contiguous with the first sidewall region 25 and parallel to the bore axis A. The stepped sidewall 28 additionally comprises an alternating series of first 28a and second 28b sidewall regions of approximately equal length. The second sidewall region 30 constitutes the first sidewall region of the second series 28b closest to the second end 24 of the feeder element 20. The first series of sidewall regions 28a consists of three sidewall regions that are perpendicular to the bore axis A. The second series of sidewall regions 28b consists of four sidewall regions. The first three sidewall regions of the second series 28b are parallel to the bore axis A. The fourth sidewall region 32 is inclined to the bore axis A at an angle of 15° and has an inwardly directed annular flange in order to minimise its footprint and thus improve knock off. The fourth sidewall region 32 is also approximately twice the length of the other sidewalls of the second series 28b.

[0043] The feeder elements and feeder sleeves were moulded as described above using a moulding pressure of 380PSI (2620kN). The feeder elements collapsed as expected and there was no visible damage to the FEEDEX HD VSK feeder sleeve, however, there was cracking and some breakages at the base of the KALMINEX 95 6/9K sleeve and KALMINEX 2000XP dome sleeve as well as some slumping (compression of the sleeve). The KALMINEX 2000XP 6/9K sleeve showed severe damage and the sleeve base was broken into several pieces. A KALMINEX 2000ZP feeder sleeve was not tested with the feeder element 20 because it is weaker than the KALMINEX XP and KALMINEX 95 feeder sleeves which suffered from damage at 380PSI (2620kN).

[0044] The series of tests were then repeated at the higher moulding pressure of 620PSI (4275kN). Again, all of the feeder elements collapsed, however this time there was visible damage to all of the sleeves. At the base of the FEEDEX HD VSK sleeve there were some small internal cracks and in one instance a chip close to the feeder element. For the KALMINEX 95 6/9K sleeve, there was more extensive cracking at the base of the sleeve and some buckling and slumping of the sleeve (the height of the sleeve was reduced by up to 10mm after moulding). The KALMINEX 2000XP flat topped dome shaped sleeve showed severe damage and the sleeve base was broken into several pieces. The KALMINEX 2000XP 6/9K sleeve was not tested.

[0045] In all instances, it was noticeable that after moulding, the first sidewall region of the collapsed feeder element was bent down past the horizontal i.e. was at an angle > 90 to the bore axis.

COMPARATIVE EXAMPLE 2 - Computer Simulation

[0046] A computer simulation (ABAQUS, manufactured by Abaqus Inc.) was conducted to evaluate the stresses imposed on a feeder system comprising a standard feeder sleeve with similar dimensions to a FEEDEX HD VSK sleeve and the feeder element 40 of figure 4. The advanced finite element analysis software includes a static and dynamic stress-strain resolver which was used for the simulations. The simulation was conducted by fixing the ' feeder element in the z-axis and then putting the model under a level of strain such that it compresses in the z-axis by a certain distance in a certain time. This puts various parts of the model under different stresses. The model was programmed with the mechanical properties of the sleeve and the feeder element, such that the stresses within the feeder sleeve can be simulated and the metal feeder element compresses.

[0047] Referring to figure 4, the feeder element 40 comprises a first end (base) 42 for mounting on a mould pattern; an opposite second end (top) 43 for receiving a feeder sleeve; and a bore 44 between the first and second ends 42, 43 defined by a stepped sidewall 45. The second end 43 is defined by a first sidewall region 46, said first sidewall region 46 being perpendicular to the bore axis A. A second sidewall region 47 is contiguous with the first sidewall region 46 and parallel to the bore axis A. The stepped sidewall 45 additionally comprises an alternating series of first 45a and second 45b sidewall regions. The second sidewall region 47 constitutes the first sidewall region of the second series 45b. The first series of sidewall regions 45a consists of two sidewall regions that are perpendicular to the bore axis A. The second series of sidewall regions 45b consists of three sidewall regions that are parallel to the bore axis A.

[0048] Figure 5a shows part of the a feeder sleeve 50 mounted on the feeder element 40 of figure 4 before moulding. Figure 5b is an enlarged view of the base of the feeder element 50 mounted on feeder element 40. Figure 5c shows an enlarged view of the same feeder sleeve 50 and feeder element 40 during moulding. The feeder sleeve cavity is indicated by arrow A. The shading, as shown in the key, represents the magnitude of the force imposed on the feeder sleeve 50. Referring to figure 5c, it can be seen that the feeder element 40 deforms under pressure as expected. Surprisingly, its mounting surface 46 is forced incrementally downward at its peripheral edge. This leads to an uneven distribution of forces with a concentration on the inner wall of the feeder sleeve 50 (point loading) as indicated by arrow B.

EXAMPLE 1 - Computer Simulation

[0049] The computer simulation of comparative example 2 suggests that the cracking observed in comparative example 1 may be caused by point loading on the inner wall of the feeder sleeve. The inventors attempted to alleviate this by changing the shape of the feeder element. The simulation was run again using the feeder element 52 of figure 6 in place of the feeder element 40 of figure 4. The inventive feeder element 52 is the same in all respects to that shown in figure 4 except that the mounting surface 54 of the feeder element 52 is inclined relative to the bore axis A at an angle of 60°. The base of the feeder sleeve 56 (figure 7a) was profiled to the same angle.

[0050] Figures 7a and 7b show the feeder element 52 and the base of the corresponding feeder sleeve 56 before and during moulding respectively. Figure 7b shows that the force is no longer concentrated on the inner wall of the feeder sleeve 56 during moulding. It is more evenly distributed along the base of the feeder sleeve 56 so that no part of the base suffers from an excessive force. It will be noted that the area of maximum force (arrow B) is in a region of the sleeve remote from the feeder sleeve cavity (arrow A). Failure in this region will not cause fragments of feeder sleeve material to enter the casting and thereby cause defects.

EXAMPLE 1 - Moulding Test

[0051] A feeder element 60 as shown in Figure 8 was tested in combination with the flat topped dome shaped feeder sleeves listed in Table 2 below (as shown in figure 9):

Table 2

	KALMINEX 2000ZP	KALMINEX 95	KALMINEX 2000XP
Manufacturing Process	Slurry formed	Slurry formed	Core shot
Density (gcm^{-3})	0.55-0.65	0.85-0.95	0.55-0.65
Strength (kN)[3]	Low (4-5)	Medium (10-11)	Medium (1-12)
a) strength of standard cylindrical test body			

[0052] The sleeve formulations vary according to the required product properties, however, all have the general formulation: 20-25 % aluminium fuel; 10-20 % oxidants and sensitisers; 5-10% organic binders; and 35-55 % refractory fillers. The type of refractory fillers used has the most direct influence on both density and strength of the sleeves.

[0053] Referring to figure 8, the feeder element 60 is identical to the feeder element 20 shown in figures 2a and 2b except that the first sidewall region 62 is inclined to the bore axis at an angle of 60°. The feeder element was manufactured from mild steel and has a thickness of 0.5mm. The maximum diameter d is 92.9mm and the height h is 35.4mm. The diameter of the bore 26 at the base of the feeder element is 22.9mm.

[0054] The feeder element 60 and feeder sleeve combinations were moulded as described above at various pressures between 420PSI (2896kPa) and 700PSI (4826kPa). The results are summarised in Table 3 below.

Table 3

Pressure	KALMINEX 2000ZP	KALMINEX 2000XP	KALMINEX 95
420PSI (2896kPa)	Sleeve buckled	No failure	No failure
460PSI (3172kPa)	Sleeve buckled	No failure	No failure
520PSI (3585kPa)	Sleeve buckled	No failure	No failure
580PSI (3999kPa)	Sleeve buckled	No failure	No failure
600PSI (4137kPa)	Sleeve buckled	No failure	No failure
700PSI (4826kPa)	Sleeve buckled	Cracked at dome	No failure
700PSI (4826kPa) Repeat test	Collapsed	Cracked at dome	Buckled on one side of sleeve

Feeder element 60 and KALMINEX 2000ZP feeder sleeve

[0055] This combination was the weakest of those tested and showed signs of failure from low moulding pressure (420PSI; 2896kPa). The feeder element did not compress fully and the feeder sleeve buckled. Despite this, there were no signs of cracking or breaking of the base of the feeder sleeve adjacent to the feeder element.

Feeder element 60 and KALMINEX 2000XP feeder sleeve

[0056] This combination was successful to moderately high pressure (700PSI; 4826kPa). The feeder sleeve eventually suffered from horizontal cracking along the dome portion of the sleeve. This was attributed to the sleeve composition (binder) and the influence of the sleeve shape and method of manufacture (core-shot). The failure was not immediately obvious, only being noticed when the sleeve was excavated from the sand mould after ram up. As expected, the level of compression of the feeder element increased with the moulding pressure until the feeder element was almost completely compressed. No sleeve debris was discovered inside the feeder sleeve therefore this mode of failure would not necessarily lead to debris falling into the casting and causing casting defects.

[0057] The flat topped dome shaped KALMINEX 2000XP feeder sleeve was employed with a conventional feeder element 20 in Comparative Example 1 where it failed at much lower pressures. At just 380PSI (2620kPa), the feeder sleeve slumped and cracked along its base and at 620PSI (4275kPa) it suffered severe damage.

Feeder element 60 and KALMINEX 95 feeder sleeve

[0058] This combination was also very successful. The feeder element 60 compressed and the first failure of the feeder sleeve occurred only at moderately high pressure (700PSI; 4826kPa). No feeder sleeve debris was discovered inside the feeder sleeve after it buckled therefore the failure would not necessarily have led to casting defects if the mould had been poured.

[0059] The KALMINEX 95 6/9K feeder sleeve was employed with a conventional feeder element 20 in Comparative Example 1 with very different results. The feeder sleeve suffered from cracking along its base at just 380PSI (2620kPa). At 620PSI (4275kPa) it suffered from more extensive cracking along its base and significant slumping. Cracking along the base is particularly problematic because chips of feeder sleeve may enter the casting.

[0060] It can be clearly seen that feeder element 60 of the present invention provides advantages over conventional feeder elements such as feeder element 20 shown in Comparative Example 1. When used in combination with feeder element 52 the medium strength feeder sleeves KALMINEX 2000XP and KALMINEX 95 are successful to much higher pressures. Further, when the feeder sleeves do eventually fail their mode of failure is less likely to lead to casting defects.

EXAMPLE 2 - Compression Test

[0061] Referring to Figure 10a, force is plotted against plate displacement for a KALMINEX 2000ZP 6/9K feeder sleeve (as shown in figure 3b) without a feeder element test piece. It will be noted that as force is increased, there is compression of the feeder sleeve associated with the natural flexibility (compressibility) of the feeder sleeve until a critical force is applied (point Z), referred to herein as the sleeve crush strength (approximately 4.5kN) after which point the compression of the sleeve proceeds steadily under a reducing loading.

[0062] Referring to Figure 10c, force is plotted against plate displacement for a feeder element test piece 10 with α=80° and a KALMINEX 2000ZP 6/9K feeder sleeve, the base of which was profiled at an angle of 80°. It will be noted that as force is increased, there is minimal compression of the feeder element and sleeve, until a critical force is applied (point A), referred to herein as the initial feeder element crush strength, after which compression proceeds rapidly under a lower loading, with point B marking the minimum force measurement after the initial feeder element test piece crush strength occurs. Further compression occurs and the force increases to a maximum (maximum feeder element crush strength, point C). When the feeder element test piece has reached or is close to its maximum displacement (point D) the force increases rapidly until the sleeve body begins to fracture. Visual inspection of the sleeve shows that at point A there is some fracturing of the bottom corner (internal base and wall) of the feeder sleeve.

[0063] Figure 10b shows the plot of force against plate displacement for a feeder element test piece 10 with α=90° and a KALMINEX 2000ZP 6/9K feeder sleeve that had a flat base.. This shows a similar but smoother curve compared to that in figure 10c (α=80°) and the initial displacement occurs at a lower applied force and continues for a long period. This is due to the initial feeder element test piece crush strength being lower but also, more significantly, it is due to damage of the feeder sleeve at the base due to the applied force from the feeder element test piece (damaging) breaking the feeder sleeve such that the feeder element is pushed up into the feeder sleeve and causes the measured displacement.

[0064] Figures 10d and 10e show the plots of force against plate displacement for feeder element test pieces 10 with α=70° and α=60° respectively when tested together with KALMINEX 2000ZP 6/9K feeder sleeves, the bases of which were profiled at an angle of 70° and 60° respectively. Comparing these plots with figure 10c (α=80°) it can be seen that the initial feeder element test piece crush strength (A) increases with decreasing α. It was also noted that the amount of visible damage to the base of the sleeve was significantly reduced and was minimal for α=70° with no fracture of the sleeve being visible.

[0065] Figures 10f and 10g show plots of force against plate displacement for feeder element test pieces with α=50° and α=40° respectively when tested together with KALMINEX 2000ZP 6/9K feeder sleeves, the bases of which were profiled at an angle of 50° and 40 ° respectively. For both of these, the initial feeder element test piece crush strength (point A) is comparable with the previously measured feeder sleeve crush strength (Z, approximately 4.5kN). However for both, there is greater displacement at point A compared to the typical sleeve crush point (point Z) due to the collapsing of the feeder element. No damage to the base of the feeder sleeve caused by the feeder element test piece was observed.

[0066] Figures 10h and 10i show plots of force against plate displacement for feeder element test pieces 10 with α=30° and α=20° respectively when tested together with KALMINEX 2000ZP 6/9K feeder sleeves, the bases of which were profiled at an angle of 30° and 20 ° respectively. Comparing these plots with figure 10g (α=40°) it can be seen that the initial feeder element crush strength (A) now decreases with decreasing α and the amount of displacement before the initial feeder element crush strength is increased. This is thought to be partly due to the distance travelled during the crushing of the feeder element test piece and partly due to a small amount of compression of the feeder sleeve into the feeder element test piece itself at the base of the feeder sleeve.

[0067] The ideal initial crush strength of the feeder element will be dependent upon the feeder sleeve (compression strength) and the moulding pressures employed. The initial feeder element crush strength should clearly be lower than the sleeve crush (compression) strength and ideally, the initial crush strength should be lower than 3000 N. If the initial crush strength is too high then moulding pressure may cause failure of the feeder sleeve before the feeder element has a chance to compress. The ideal maximum crush strength is very much dependent on the application for which the feeder element core is intended i.e. the moulding pressure employed and the sleeve composition (strength). If the maximum crush strength were too high for the moulding pressures employed, then there would be insufficient collapsing of the feeder element and subsequently insufficient sand compaction. In addition, it would limit the type (strength) of sleeves that could be successfully employed.

Claims

1. A feeder element (52; 60) for use in metal casting, said feeder element (52; 60) comprising:

   a first end for mounting on a mould pattern;
   an opposite second end for receiving a feeder sleeve; and
   a bore between the first and second ends defined by a stepped sidewall; said feeder element (52; 60) being compressible in use whereby to reduce the distance between the first and second ends, wherein the stepped sidewall has a first sidewall region (54; 62) defining the second end of the element and a mounting surface for a feeder sleeve in use, and a second sidewall region contiguous with the first sidewall region, said second sidewall region being parallel to or inclined to the bore axis at a different angle to the first sidewall region (54; 62) whereby to define a step in the sidewall,
   characterised in that
   said first sidewall region (54; 62) is inclined to the bore axis by less than 90°.

2. The feeder element of claim 1 comprising additional sidewall regions, whereby multiple steps in the sidewall are defined.

3. The feeder element of claim 2, wherein at least one of the additional sidewall regions is inclined at a greater angle to the axis than the first sidewall region.

4. The feeder element of any preceding claim, wherein the first sidewall region (54; 62) is inclined to the bore axis at an angle of between 5 ° and 85°.

5. The feeder element of any preceding claim, wherein the first sidewall region (54; 62) is inclined to the bore axis at an angle of between 30° and 70°.

6. The feeder element of any preceding claim, wherein the initial crush strength is no more than 5000 N.

7. The feeder element of any preceding claim, wherein the initial crush strength is at least 250 N.

8. The feeder element of any preceding claim, wherein said compression in use is non-reversible.

9. The feeder element of any preceding claim, wherein the stepped sidewall of the feeder element comprises a first series of sidewall regions in the form of rings interconnected and integrally formed with a second series of sidewall regions.

10. The feeder element of claim 9, which is defined by the first sidewall region and one each of the first and second series of sidewall regions.

11. The feeder element of claim 9 or 10, wherein the thickness of the sidewall regions is 0.2 to 1.5 mm.

12. The feeder element as claimed in any one of claims 9 to 11, wherein said rings are circular.

13. The feeder element of any one of claims 9 to 12, wherein said rings are planar.

14. The feeder element of any one of claims 9 to 13, wherein the sidewall regions are of substantially uniform thickness, so that the diameter of the bore of the feeder element increases from the first end to the second end of the feeder element.

15. The feeder element of any one of claims 9 to 14, wherein the second series of sidewall regions are annular.

16. The feeder element of any one of claims 9 to 15, wherein the first end of the feeder element is defined by a sidewall region having a greater length than the other sidewall regions of the corresponding series.

17. The feeder element of any one of claims 9 to 16, wherein the sidewall region defining the first end of the feeder element is inclined to the bore axis by an angle of 5 to 30°.

18. The feeder element of any one of claims 9 to 17, wherein the thickness of the sidewall regions is from 4 to 24% of the distance between the inner and outer diameters of the first sidewall region(s).

19. The feeder element of claim 18, wherein a free edge of the sidewall region defining the first end of the feeder element has an inwardly directed annular flange or bead.

20. A feeder system for metal casting comprising a feeder element (52; 60) in accordance with any one of claims 1 to 19 and a feeder sleeve secured thereto.

21. A feeder system in accordance with claim 20, in which the feeder sleeve is secured to the feeder element (52; 60) by adhesive or by being a push fit with the feeder element or by moulding the sleeve around part of the feeder element. '

22. A feeder system in accordance with claim 20 or 21, wherein the base of the feeder sleeve is profiled at the same angle as the first sidewall region (54; 62) of the feeder element (52; 60) of any one of claims 1 to 20.

23. A feeder system in accordance with any one of claims 20 to 22, wherein the sleeve strength is at least 5kN and less than 20kN.

Patentansprüche

1. Speiserelement (52; 60) zur Verwendung beim Metallgießen, wobei das Speiserelement (52; 60) Folgendes umfasst:

ein erstes Ende zum Anbringen an einem Gussmodell,
ein entgegengesetztes zweites Ende zum Aufnehmen eines Speisereinsatzes, und
eine Bohrung zwischen dem ersten und dem zweiten Ende, die durch eine abgestufte Seitenwand definiert wird, wobei das Speiserelement (52; 60) bei Anwendung zusammengedrückt werden kann, um **dadurch** den Abstand zwischen dem ersten und dem zweiten Ende zu verringern, wobei die abgestufte Seitenwand einen ersten Seitenwandbereich (54; 62), der das zweite Ende des Elements und eine Anbringungsfläche für einen Speisereinsatz bei Anwendung definiert, und einen zweiten Seitenwandbereich, der mit dem ersten Seitenwandbereich aneinanderstößt, hat, wobei der zweite Seitenwandbereich parallel zu der Bohrungsachse oder in einem anderen Winkel als der erste Seitenwandbereich (54; 62) zu derselben geneigt ist, um **dadurch** eine Stufe in der Seitenwand zu definieren,
dadurch gekennzeichnet, dass
der erste Seitenwandbereich (54; 62) um weniger als 90° zu der Bohrungsachse geneigt ist.

2. Speiserelement nach Anspruch 1, das zusätzliche Seitenwandbereiche umfasst, wodurch mehrere Stufen in der Seitenwand definiert werden.

3. Speiserelement nach Anspruch 2, wobei wenigstens einer der zusätzlichen Seitenwandbereiche in einem größeren Winkel zu der Bohrungsachse geneigt ist als der erste Seitenwandbereich.

4. Speiserelement nach einem der vorhergehenden Ansprüche, wobei der erste Seitenwandbereich (54; 62) in einem Winkel zwischen 5° und 85° zu der Bohrungsachse geneigt ist.

5. Speiserelement nach einem der vorhergehenden Ansprüche, wobei der erste Seitenwandbereich (54; 62) in einem Winkel zwischen 30° und 70° zu der Bohrungsachse geneigt ist.

6. Speiserelement nach einem der vorhergehenden Ansprüche, wobei die anfängliche Druckfestigkeit nicht mehr als 5000 N beträgt.

7. Speiserelement nach einem der vorhergehenden Ansprüche, wobei die anfängliche Druckfestigkeit wenigstens 250 N beträgt.

8. Speiserelement nach einem der vorhergehenden Ansprüche, wobei die Kompression bei Anwendung unumkehrbar ist.

9. Speiserelement nach einem der vorhergehenden Ansprüche, wobei die abgestufte Seitenwand des Speiserelements eine erste Reihe von Seitenwandbereichen in der Form von Ringen umfasst, die mit einer zweiten Reihe von Seitenwandbereichen wechselseitig verbunden und integral geformt ist.

10. Speiserelement nach Anspruch 9, das durch den ersten Seitenwandbereich und jeweils einen der ersten und der zweiten Reihe von Seitenwandbereichen definiert wird.

11. Speiserelement nach Anspruch 9 oder 10, wobei die Dicke der Seitenwandbereiche 0,2 bis 1,5 mm beträgt.

12. Speiserelement nach einem der Ansprüche 9 bis 11, wobei die Ringe kreisförmig sind.

13. Speiserelement nach einem der Ansprüche 9 bis 12, wobei die Ringe eben sind.

14. Speiserelement nach einem der Ansprüche 9 bis 13, wobei die Seitenwandbereiche eine im Wesentlichen gleichförmige Dicke haben, so dass der Durchmesser der Bohrung des Speiserelements von dem ersten Ende zu dem zweiten Ende des Speiserelements zunimmt.

15. Speiserelement nach einem der Ansprüche 9 bis 14, wobei die zweite Reihe von Seitenwandbereichen ringförmig ist.

16. Speiserelement nach einem der Ansprüche 9 bis 15, wobei das erste Ende des Speiserelements durch einen Seitenwandbereich definiert wird, der eine größere Länge hat als die anderen Seitenwandbereiche der entsprechenden Reihe.

17. Speiserelement nach einem der Ansprüche 9 bis 16, wobei der Seitenwandbereich, der das erste Ende des Speiserelements definiert, um einen Winkel von 5 bis 30° zu der Bohrungsachse geneigt ist.

18. Speiserelement nach einem der Ansprüche 9 bis 17, wobei die Dicke der Seitenwandbereiche von 4 bis 24 % des Abstandes zwischen dem Innen- und dem Außendurchmesser des/der ersten Seitenwandbereichs/e beträgt.

19. Speiserelement nach Anspruch 18, wobei eine freie Kante des Seitenwandbereichs, der das erste Ende des Speiserelements definiert, einen nach innen gerichteten Flansch oder Wulst hat.

20. Speisersystem zum Metallgießen, das ein Speiserelement (52; 60) nach einem der Ansprüche 1 bis 19 und einen an demselben befestigten Speisereinsatz umfasst.

21. Speisersystem nach Anspruch 20, wobei der Speisereinsatz durch einen Klebstoff oder **dadurch**, dass er in Schiebepassung mit dem Speiserelement ist, oder durch Formen des Einsatzes um einen Teil des Speiserelements an dem Speiserelement (52; 60) befestigt ist.

22. Speisersystem nach Anspruch 20 oder 21, wobei die Basis des Speisereinsatzes in dem gleichen Winkel profiliert ist wie der erste Seitenwandbereich (54; 62) des Speiserelements (52; 60) nach einem der Ansprüche 1 bis 20.

23. Speisersystem nach einem der Ansprüche 20 bis 22, wobei die Einsatzfestigkeit wenigstens 5 kN und weniger als 20 kN beträgt.

Revendications

1. Elément de masselotte (52 ; 60), destiné à être utilisé dans la coulée de métal, ledit élément de masselotte (52 ; 60) comprenant :

une première extrémité en vue du montage sur un modèle de moule ;
une deuxième extrémité opposée pour recevoir une douille de masselotte ; et
un alésage entre les première et deuxième extrémités, défini par une paroi latérale étagée ;
ledit élément de masselotte (52 ; 60) pouvant être comprimé en service, pour réduire ainsi la distance entre les première et deuxième extrémités, la paroi latérale étagée comportant une première région de paroi latérale (54 ; 62) définissant la deuxième extrémité de l'élément ; et une surface de montage pour la douille de masselotte en service, et une deuxième région de paroi latérale contiguë à la première région de paroi latérale, ladite deuxième région de paroi latérale étant parallèle à l'axe de l'alésage ou inclinée par rapport à celui-ci à un angle différent de celui de la première région de paroi latérale (54 ; 62), pour définir ainsi un étage dans la paroi latérale ;
caractérisé en ce que
ladite première région de paroi latérale (54 ; 62) est inclinée par rapport à l'axe de l'alésage à un angle inférieur à 90°.

2. Elément de masselotte selon la revendication 1, comprenant des régions de paroi latérale additionnelles, définissant ainsi de multiples étages dans la paroi latérale.

3. Elément de masselotte selon la revendication 2, dans lequel au moins une des régions de paroi latérale additionnelles est inclinée par rapport à l'axe à un angle supérieur à celui de la première région de paroi latérale.

4. Elément de masselotte selon l'une quelconque des revendications précédentes, dans lequel la première région de paroi latérale (54 ; 62) est inclinée par rapport à l'axe de l'alésage à un angle compris entre 5° et 85°.

5. Elément de masselotte selon l'une quelconque des revendications précédentes, dans lequel la première région de paroi latérale (54 ; 62) est inclinée par rapport à l'axe de l'alésage à un angle compris entre 30° et 70°.

6. Elément de masselotte selon l'une quelconque des revendications précédentes, dans lequel la résistance à l'écrasement initiale n'est pas supérieure à 5000 N.

7. Elément de masselotte selon l'une quelconque des revendications précédentes, dans lequel la résistance à l'écrasement initiale correspond au moins à 250 N.

8. Elément de masselotte selon l'une quelconque des revendications précédentes, dans lequel ladite compression en service est irréversible.

9. Elément de masselotte selon l'une quelconque des revendications précédentes, dans lequel la paroi latérale étagée de l'élément de masselotte comprend une première série de régions de paroi latérale sous forme de bagues interconnectées et formées d'une seule pièce avec une deuxième série de régions de paroi latérale.

10. Elément de masselotte selon la revendication 9, défini par la première région de paroi latérale et l'une de chacune des première et deuxième séries de régions de paroi latérale.

11. Elément de masselotte selon les revendications 9 ou 10, dans lequel l'épaisseur des régions de paroi latérale est comprise entre 0,2 et 1,5 mm.

12. Elément de masselotte selon l'une quelconque des revendications 9 à 11, dans lequel lesdites bagues sont circulaires.

13. Elément de masselotte selon l'une quelconque des revendications 9 à 12, dans lequel lesdites bagues sont planes.

14. Elément de masselotte selon l'une quelconque des revendications 9 à 13, dans lequel les régions de paroi latérale ont une épaisseur pratiquement uniforme, de sorte que le diamètre de l'alésage de l'élément de masselotte est accru de la première extrémité vers la deuxième extrémité de l'élément de masselotte.

15. Elément de masselotte selon l'une quelconque des revendications 9 à 14, dans lequel la deuxième série de régions de paroi latérale est annulaire.

16. Elément de masselotte selon l'une quelconque des revendications 9 à 15, dans lequel la première extrémité de l'élément de masselotte est définie par une région de paroi latérale ayant une longueur supérieure à celle des autres régions de paroi latérale de la série correspondante.

17. Elément de masselotte selon l'une quelconque des revendications 9 à 16, dans lequel la région de paroi latérale définissant la première extrémité de l'élément de masselotte est inclinée par rapport à l'axe de l'alésage à un angle compris entre 5 et 30°.

18. Elément de masselotte selon l'une quelconque des revendications 9 à 17, dans lequel l'épaisseur des régions de paroi latérale représente 4 à 24% de la distance enter les diamètres intérieur et extérieur des premières (de la première) région(s) de paroi latérale.

19. Elément de masselotte selon la revendication 18, dans lequel un bord libre de la région de paroi latérale définissant la première extrémité de l'élément de masselotte comporte une bride ou une moulure annulaire dirigée vers l'intérieur.

20. Système à masselotte pour la coulée de métal, comprenant un élément de masselotte (52 ; 60) selon l'une quelconque des revendications 1 à 19, et une douille de masselotte qui y est fixée.

21. Système à masselotte selon la revendication 20, dans lequel la douille de masselotte est fixée sur l'élément de masselotte (52 ; 60) par un adhésif, par ajustement par poussée sur l'élément de masselotte ou par moulage de la douille autour d'une partie de l'élément de masselotte.

22. Système à masselotte selon les revendications 20 ou 21, dans lequel la base de la douille de masselotte est profilée à un angle identique à celle de la première région de paroi latérale (54 ; 62) de l'élément de masselotte (52 ; 60) selon l'une quelconque des revendications 1 à 20.

23. Système à masselotte selon l'une quelconque des revendications 20 à 22, dans lequel la résistance de la douille correspond au moins à 5 kN et est inférieure à 20 kN.

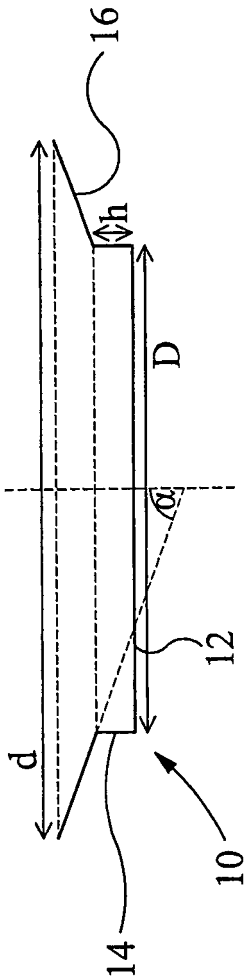


FIG 1

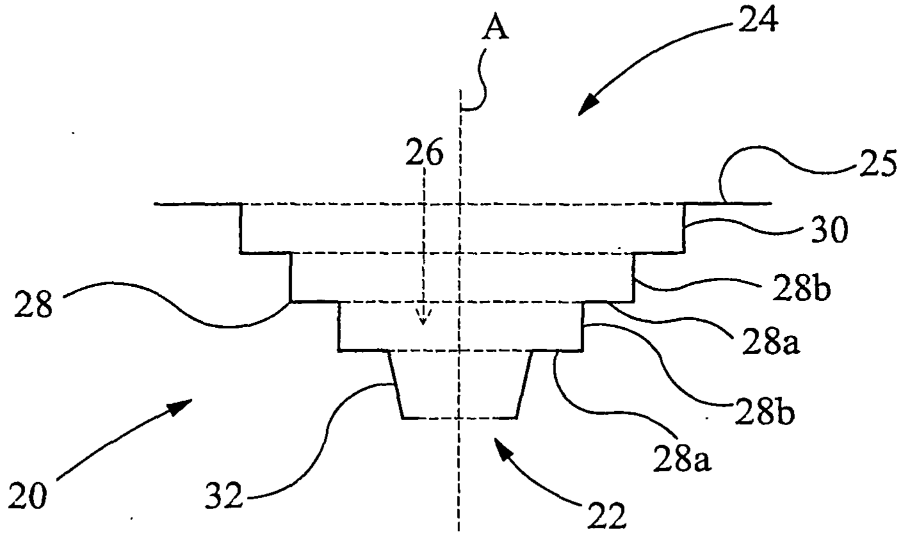


FIG 2a

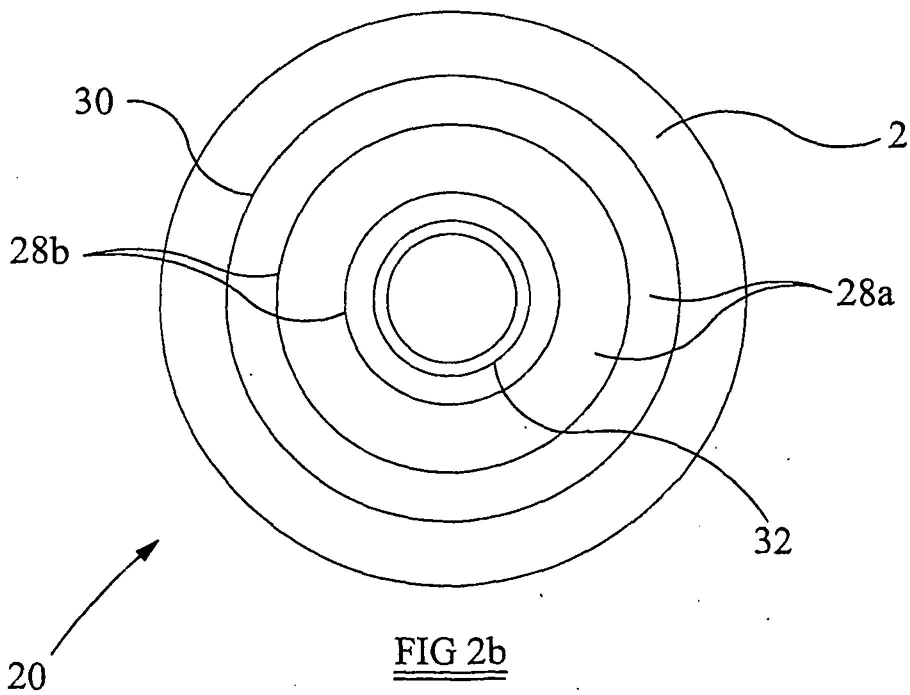


FIG 2b

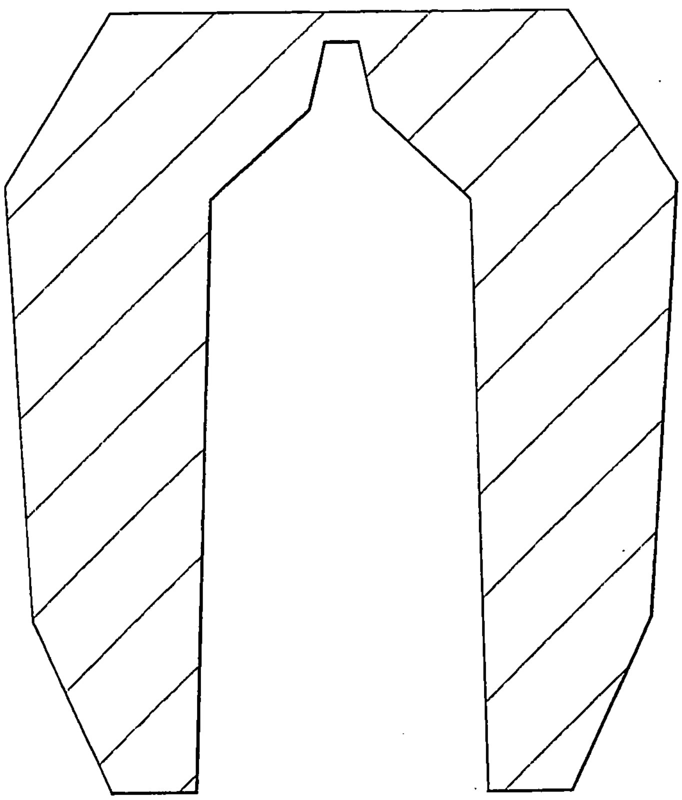


FIG 3a

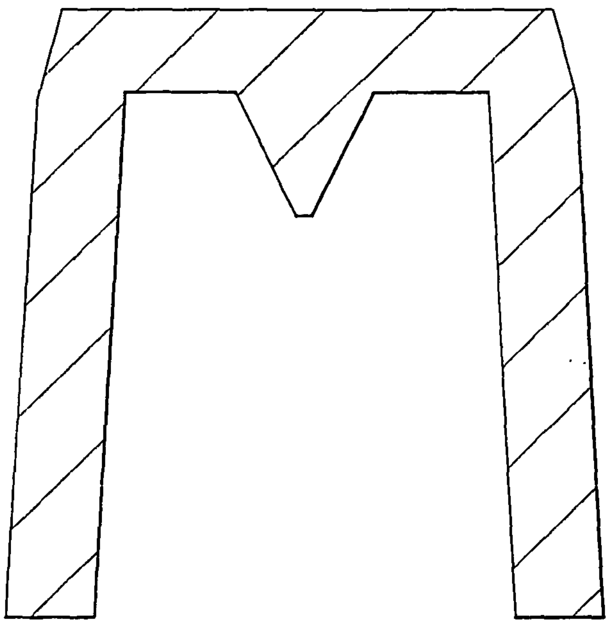


FIG 3b

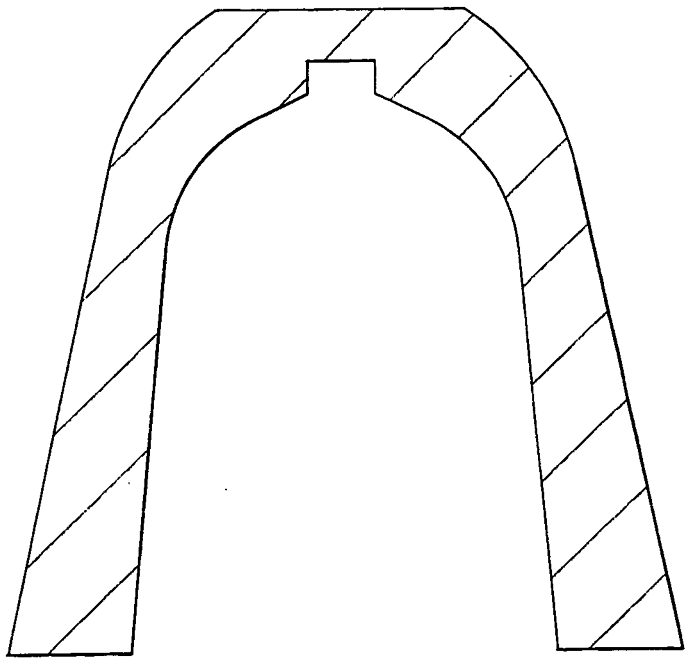


FIG 3c

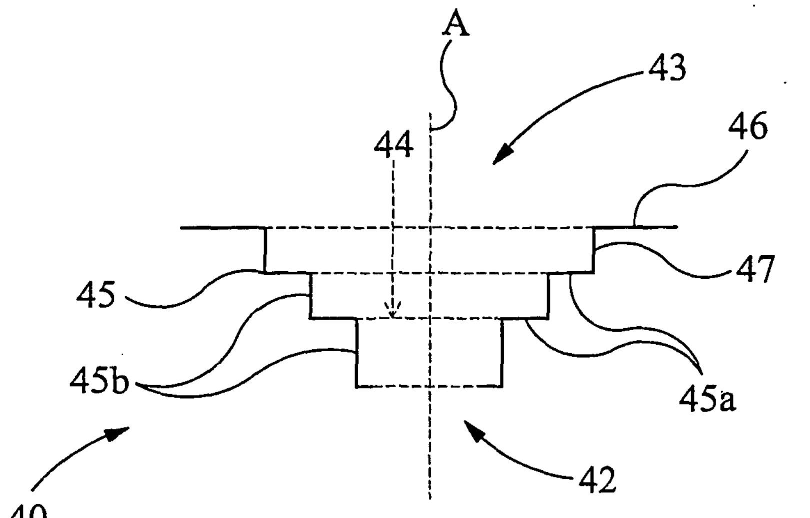


FIG 4

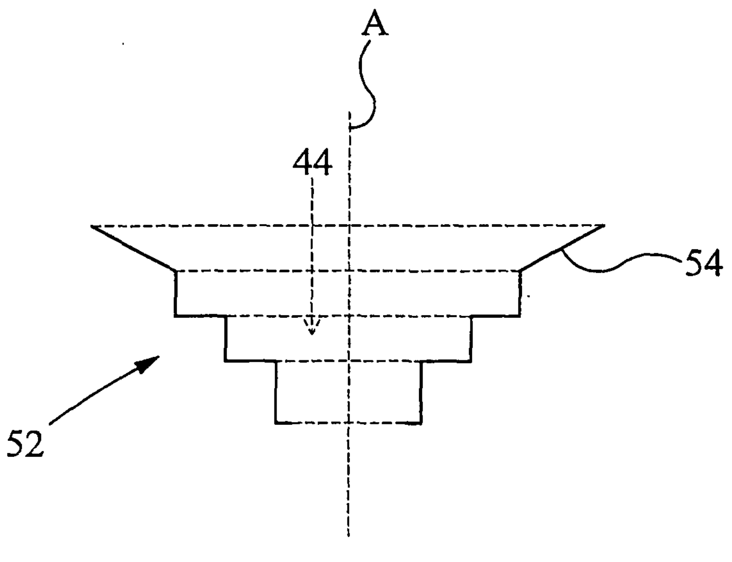


FIG 6

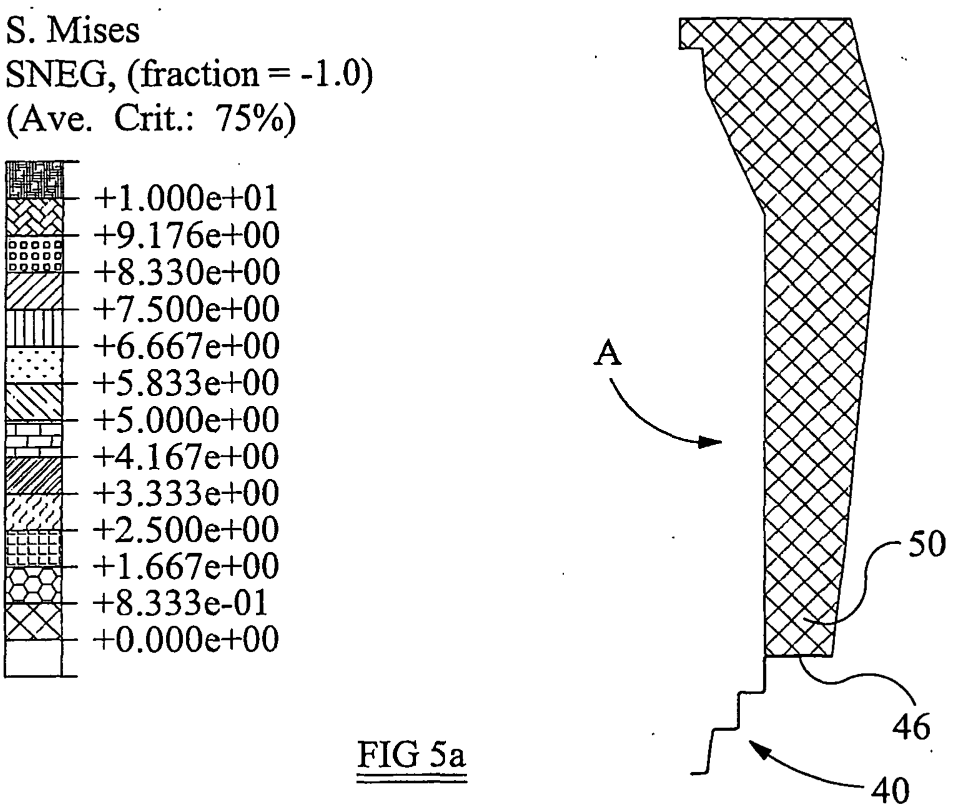

S. Mises
SNEG, (fraction = -1.0)
(Ave. Crit.: 75%)
+1.000e+01
+9.176e+00
+8.330e+00
+7.500e+00
+6.667e+00
+5.833e+00
+5.000e+00
+4.167e+00
+3.333e+00
+2.500e+00
+1.667e+00
+8.333e-01
+0.000e+00
A
50
46
40

FIG 5a

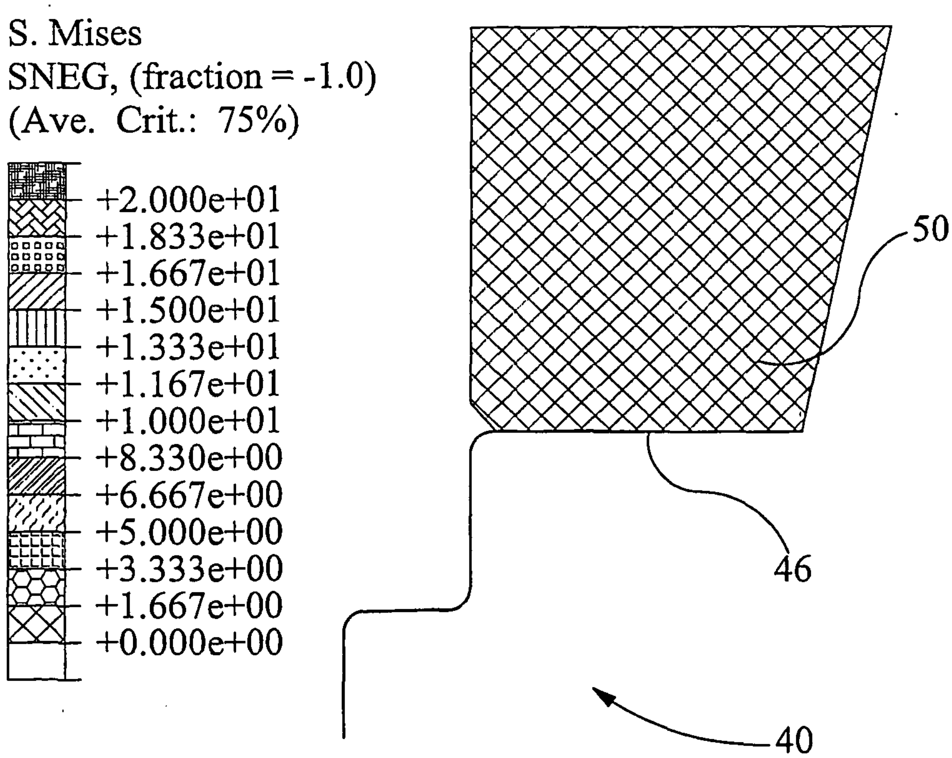

S. Mises
SNEG, (fraction = -1.0)
(Ave. Crit.: 75%)
+2.000e+01
+1.833e+01
+1.667e+01
+1.500e+01
+1.333e+01
+1.167e+01
+1.000e+01
+8.330e+00
+6.667e+00
+5.000e+00
+3.333e+00
+1.667e+00
+0.000e+00
50
46
40

FIG 5b

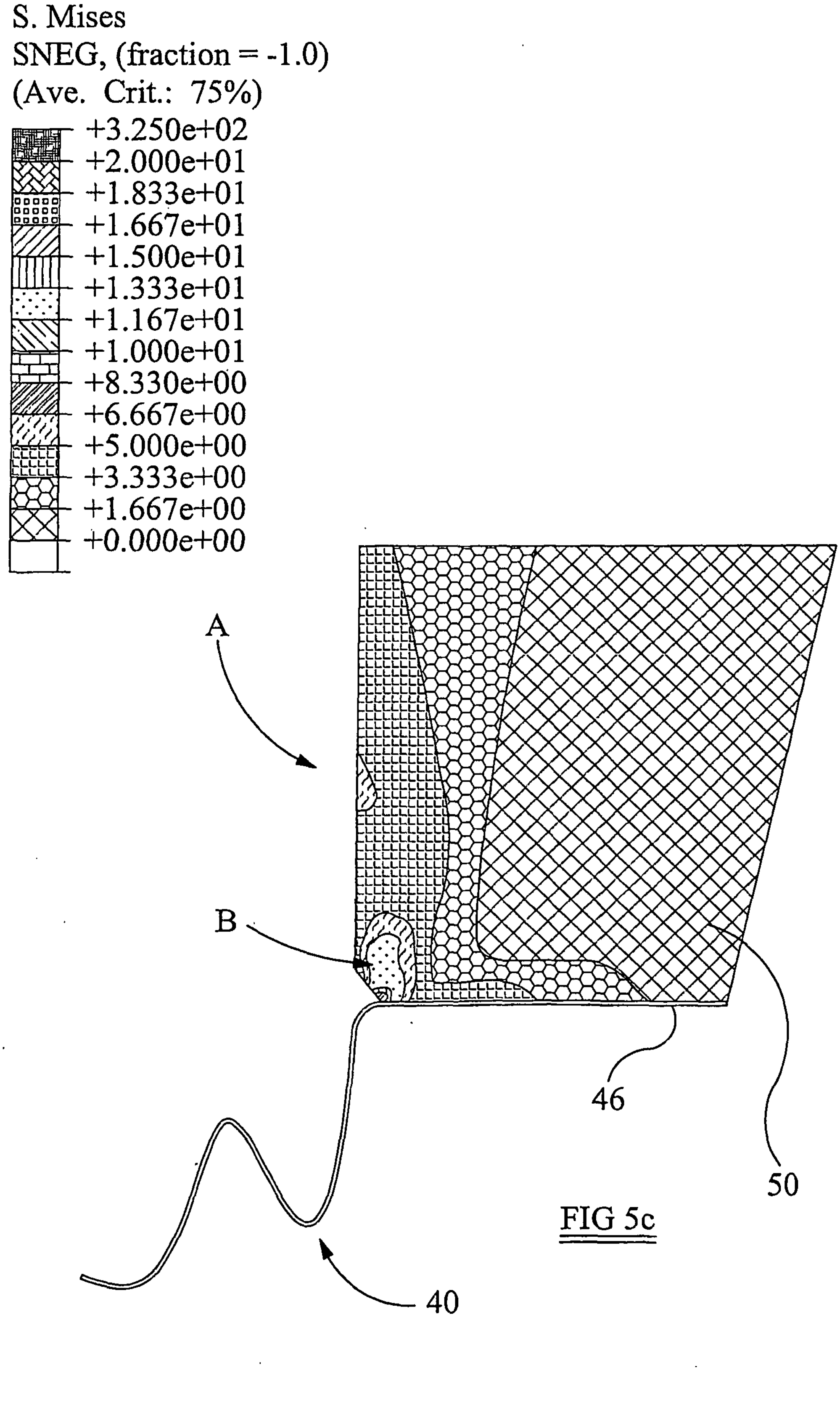

S. Mises
SNEG, (fraction = -1.0)
(Ave. Crit.: 75%)
+3.250e+02
+2.000e+01
+1.833e+01
+1.667e+01
+1.500e+01
+1.333e+01
+1.167e+01
+1.000e+01
+8.330e+00
+6.667e+00
+5.000e+00
+3.333e+00
+1.667e+00
+0.000e+00
A
B
46
50
40

FIG 5c

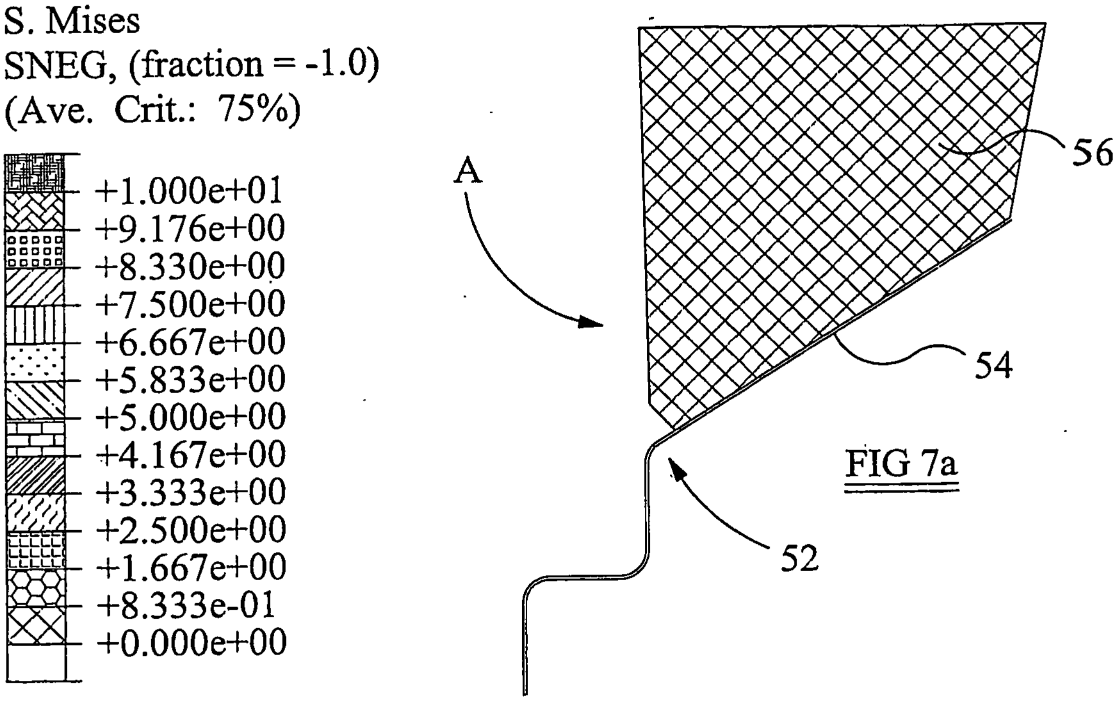

S. Mises
SNEG, (fraction = -1.0)
(Ave. Crit.: 75%)
+1.000e+01
+9.176e+00
+8.330e+00
+7.500e+00
+6.667e+00
+5.833e+00
+5.000e+00
+4.167e+00
+3.333e+00
+2.500e+00
+1.667e+00
+8.333e-01
+0.000e+00
A
56
54
52

FIG 7a

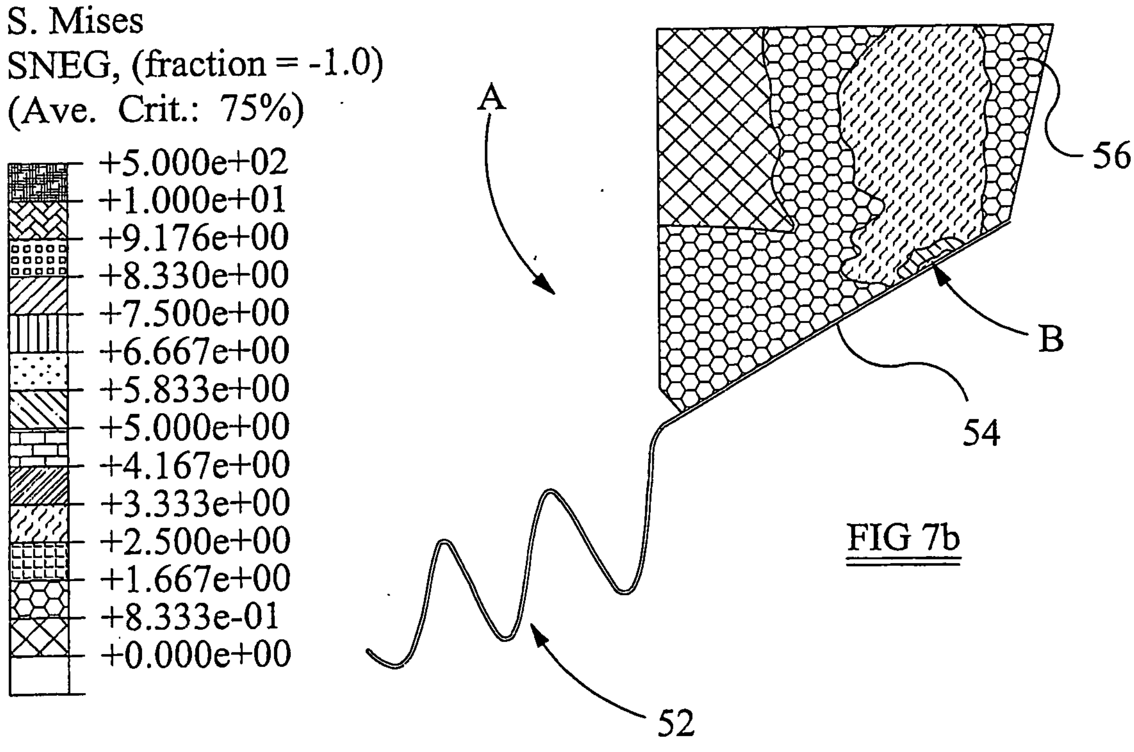

S. Mises
SNEG, (fraction = -1.0)
(Ave. Crit.: 75%)
+5.000e+02
+1.000e+01
+9.176e+00
+8.330e+00
+7.500e+00
+6.667e+00
+5.833e+00
+5.000e+00
+4.167e+00
+3.333e+00
+2.500e+00
+1.667e+00
+8.333e-01
+0.000e+00
A
56
B
54
52

FIG 7b

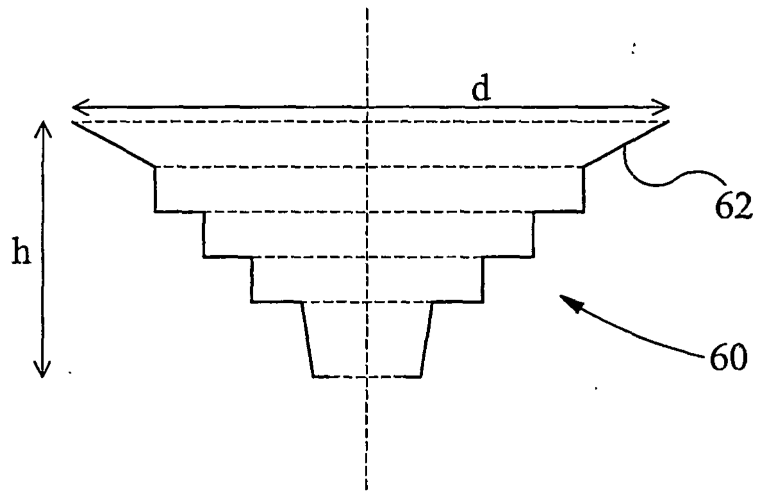


FIG 8

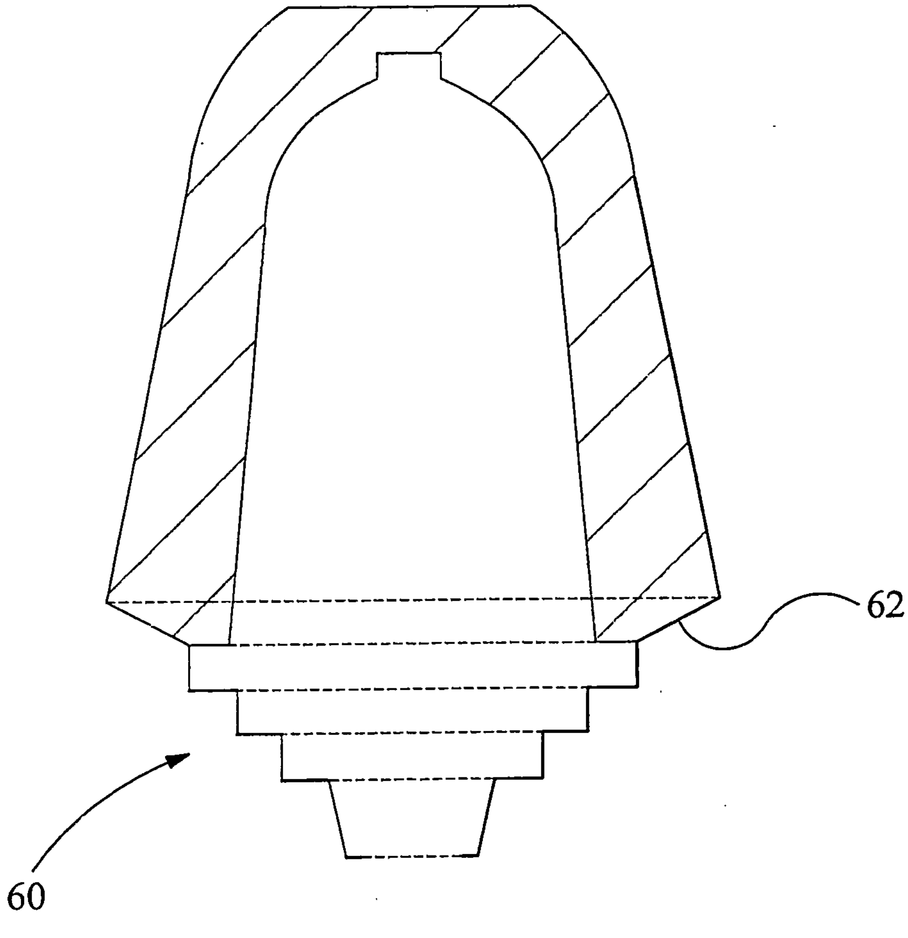


FIG 9

FIG 10a - KALMINEX 2000ZP 6/9

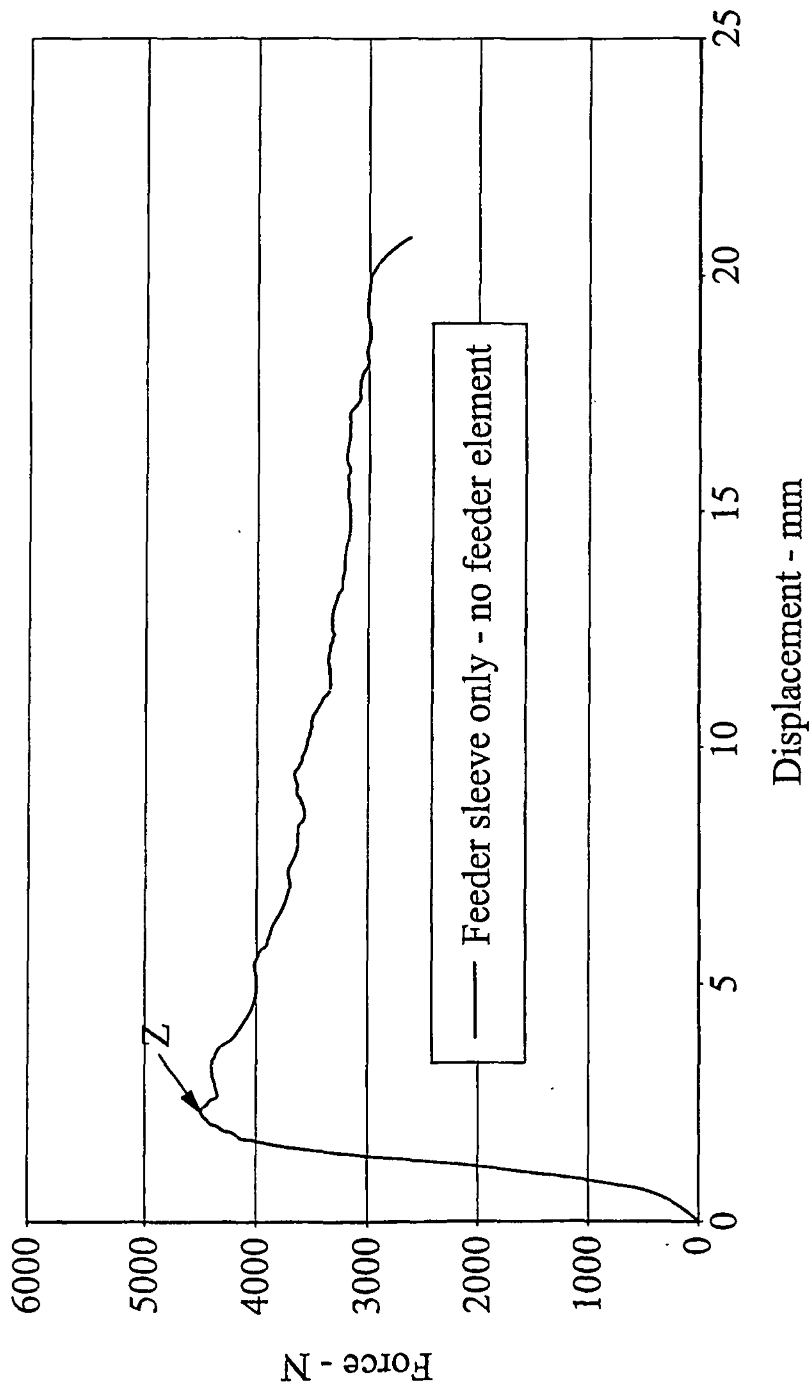


FIG 10b - KALMINEX 2000ZP 6/9 - 90 deg

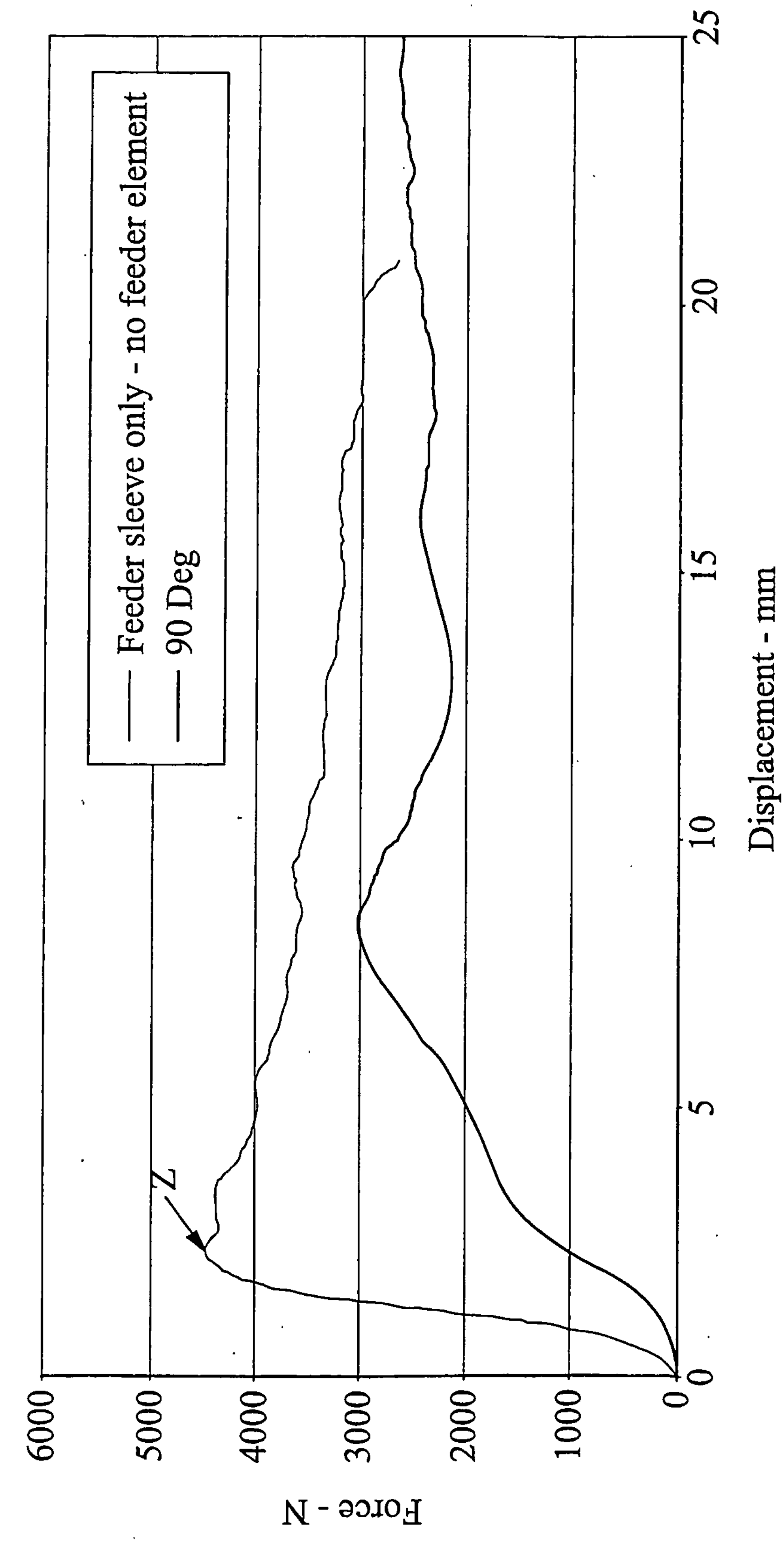


FIG 10c - KALMINEX 2000ZP 6/9 - 80 deg

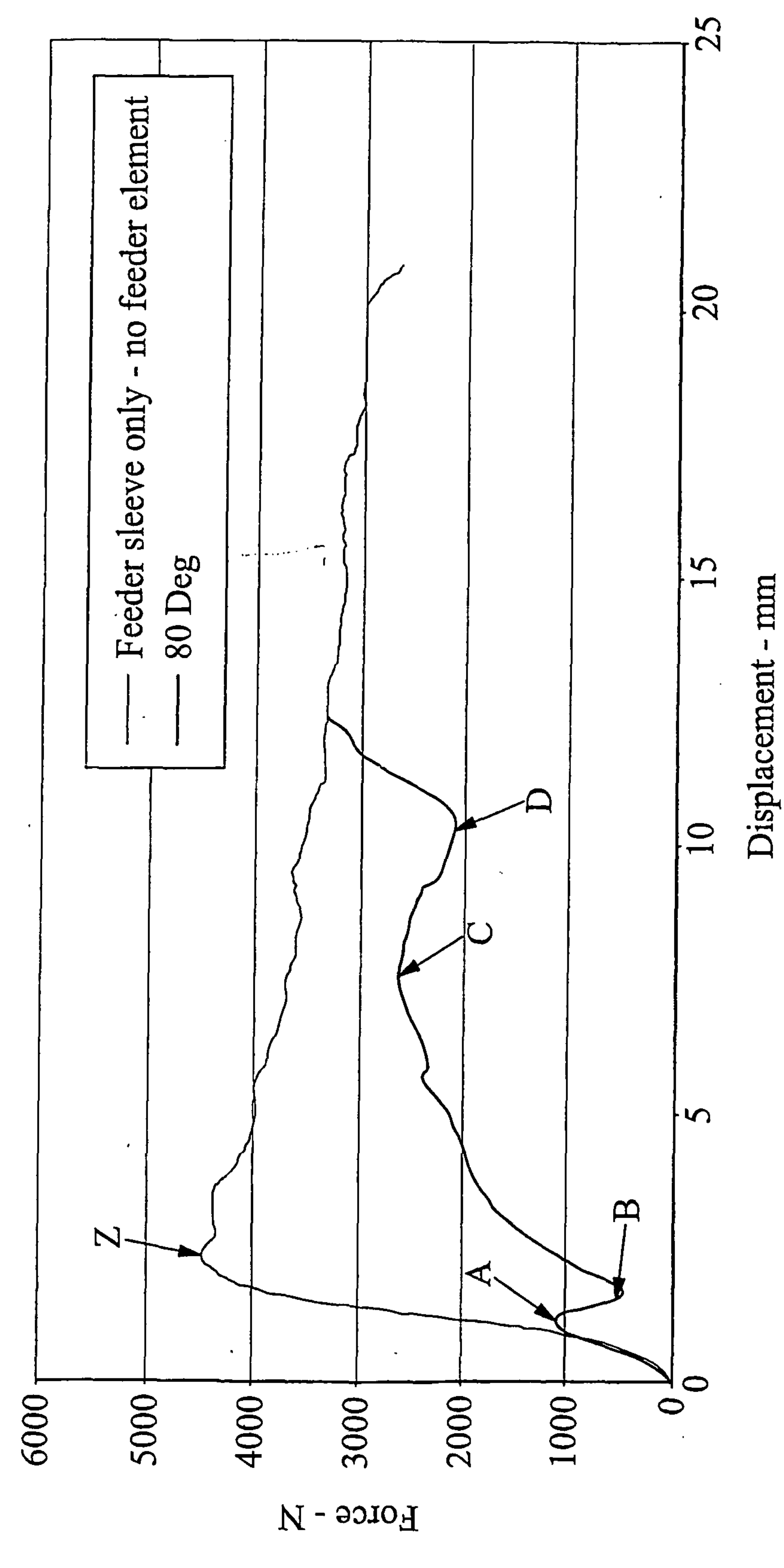


FIG 10d - KALMINEX 2000ZP 6/9 - 70 deg

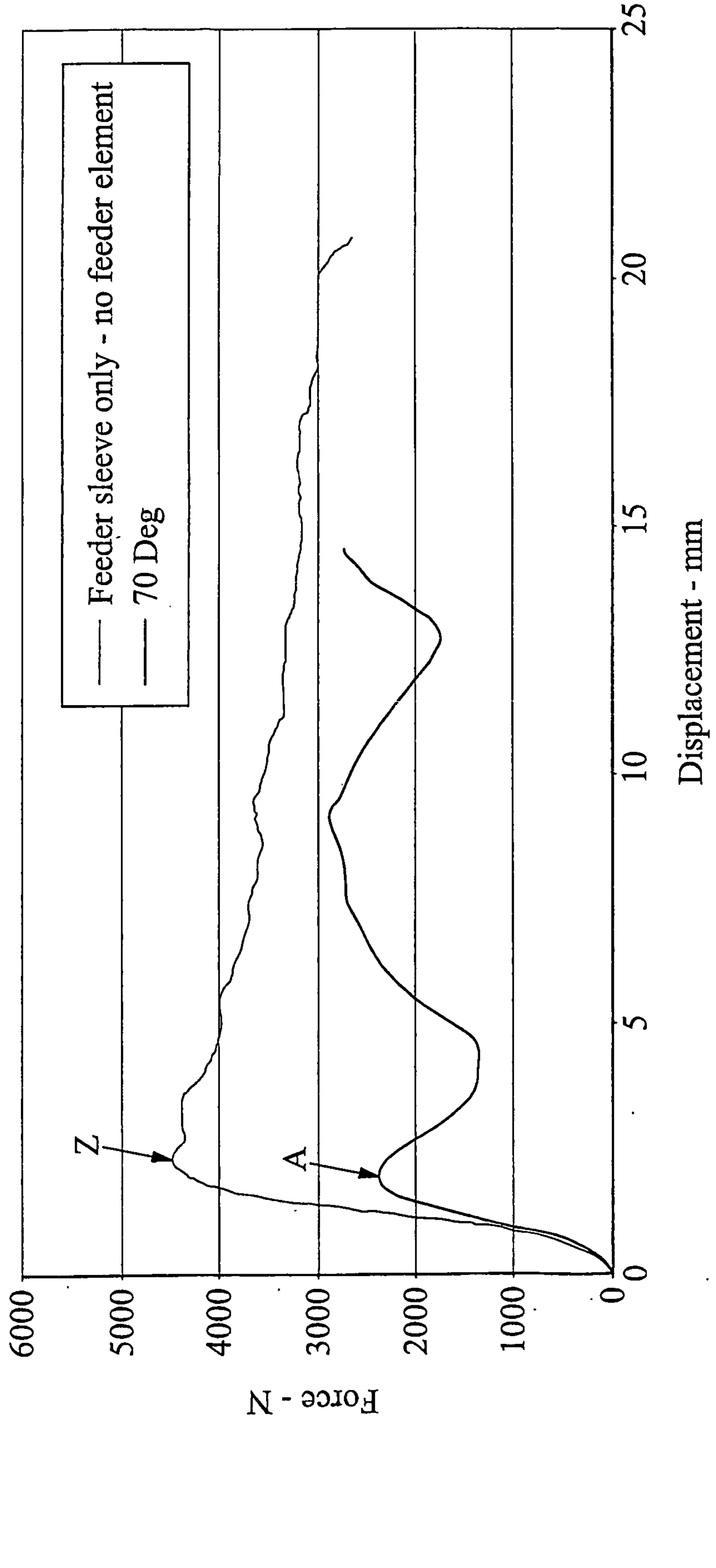


FIG 10e - KALMINEX 2000ZP 6/9 - 60 deg

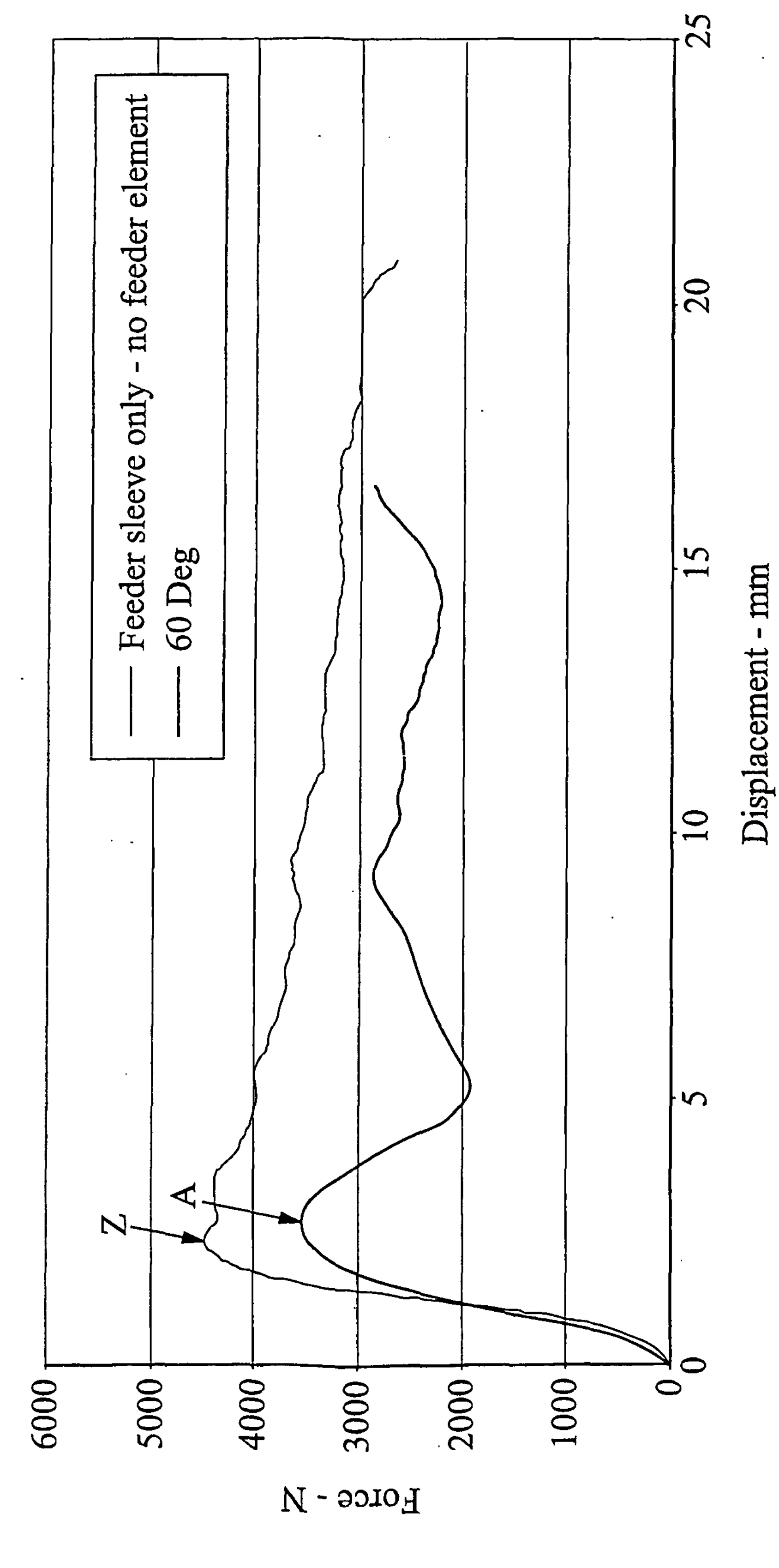


FIG 10f - KALMINEX 2000ZP 6/9 - 50 deg

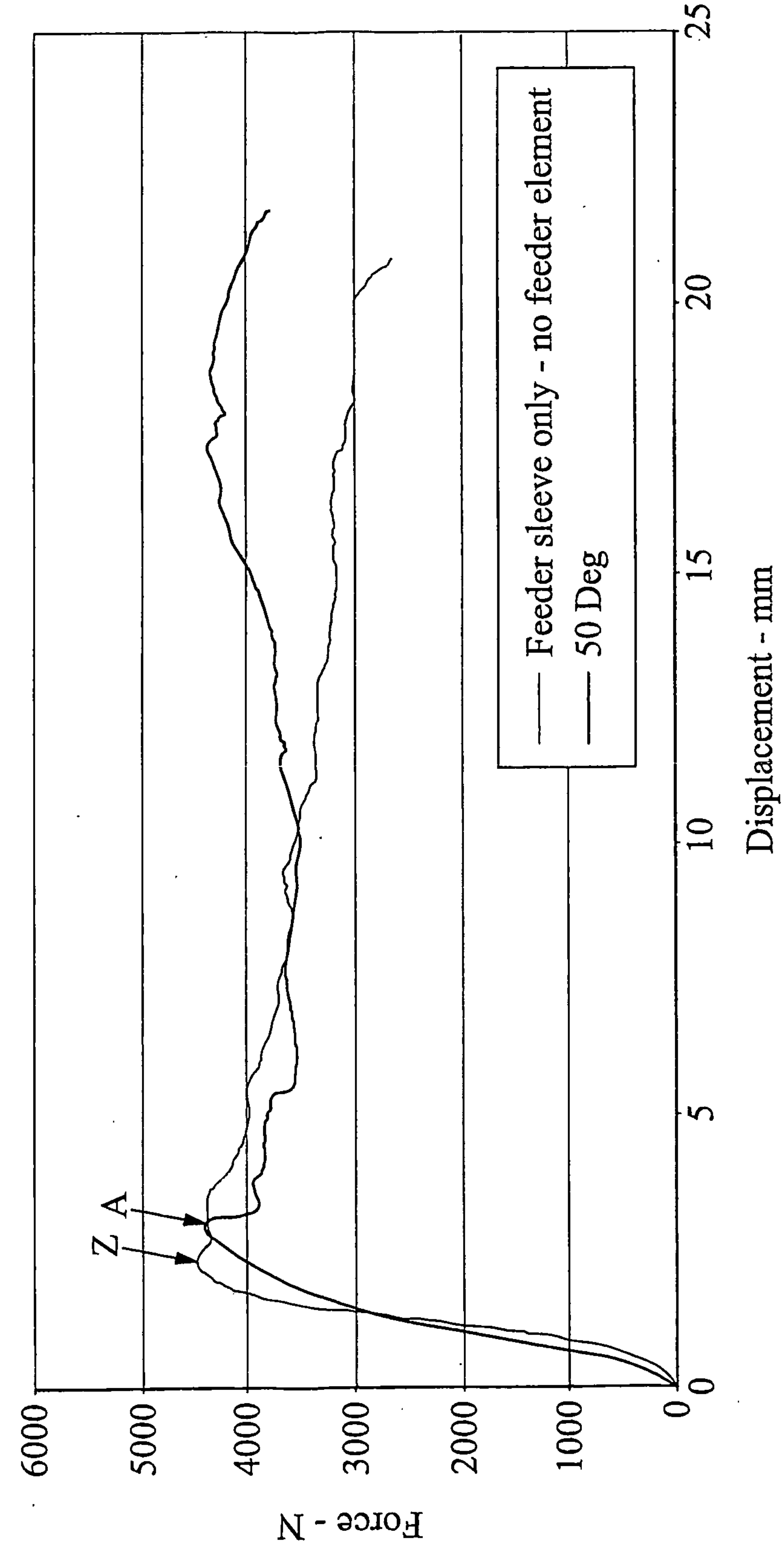


FIG 10g - KALMINEX 2000ZP 6/9 - 40 deg

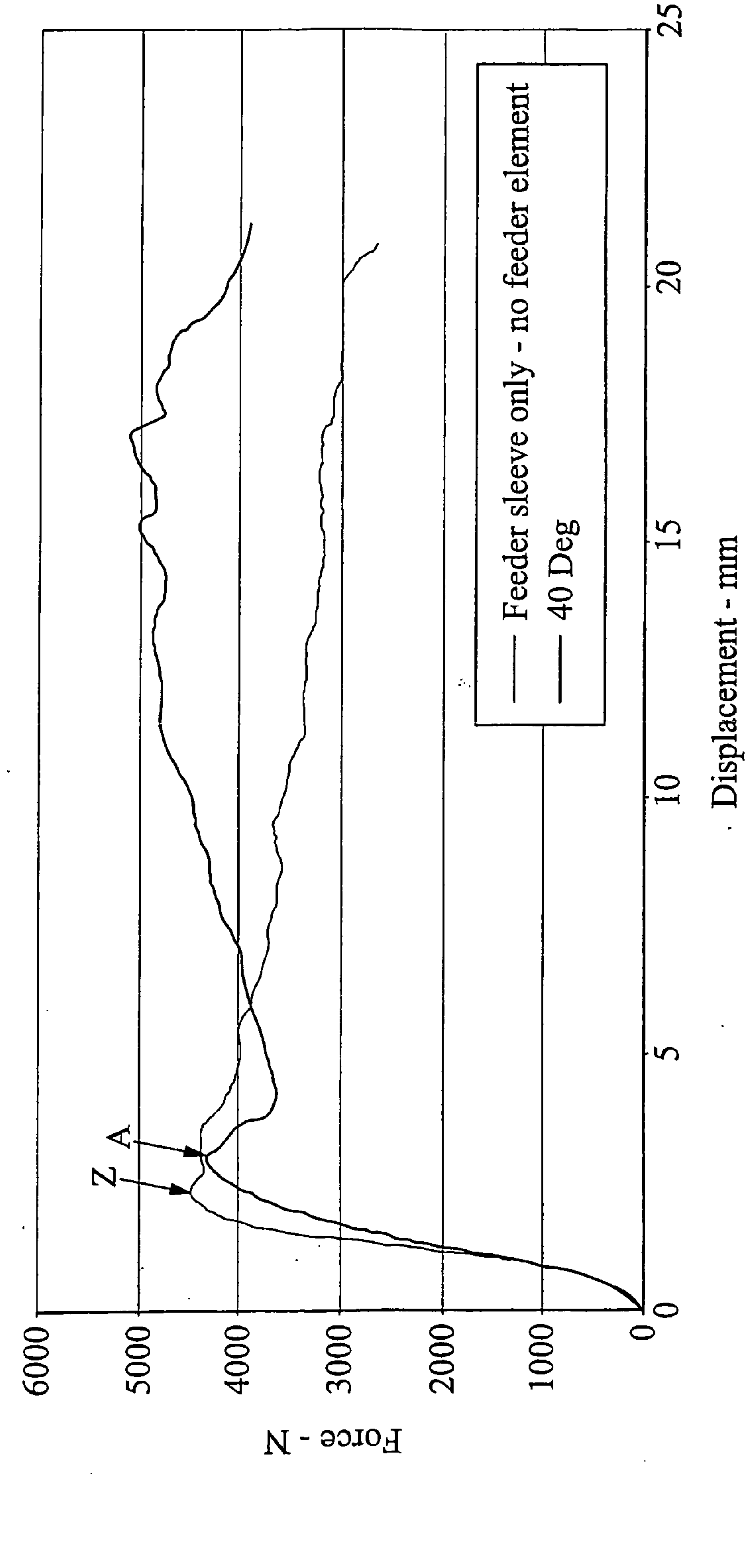


FIG 10h - KALMINEX 2000ZP 6/9 - 30 deg

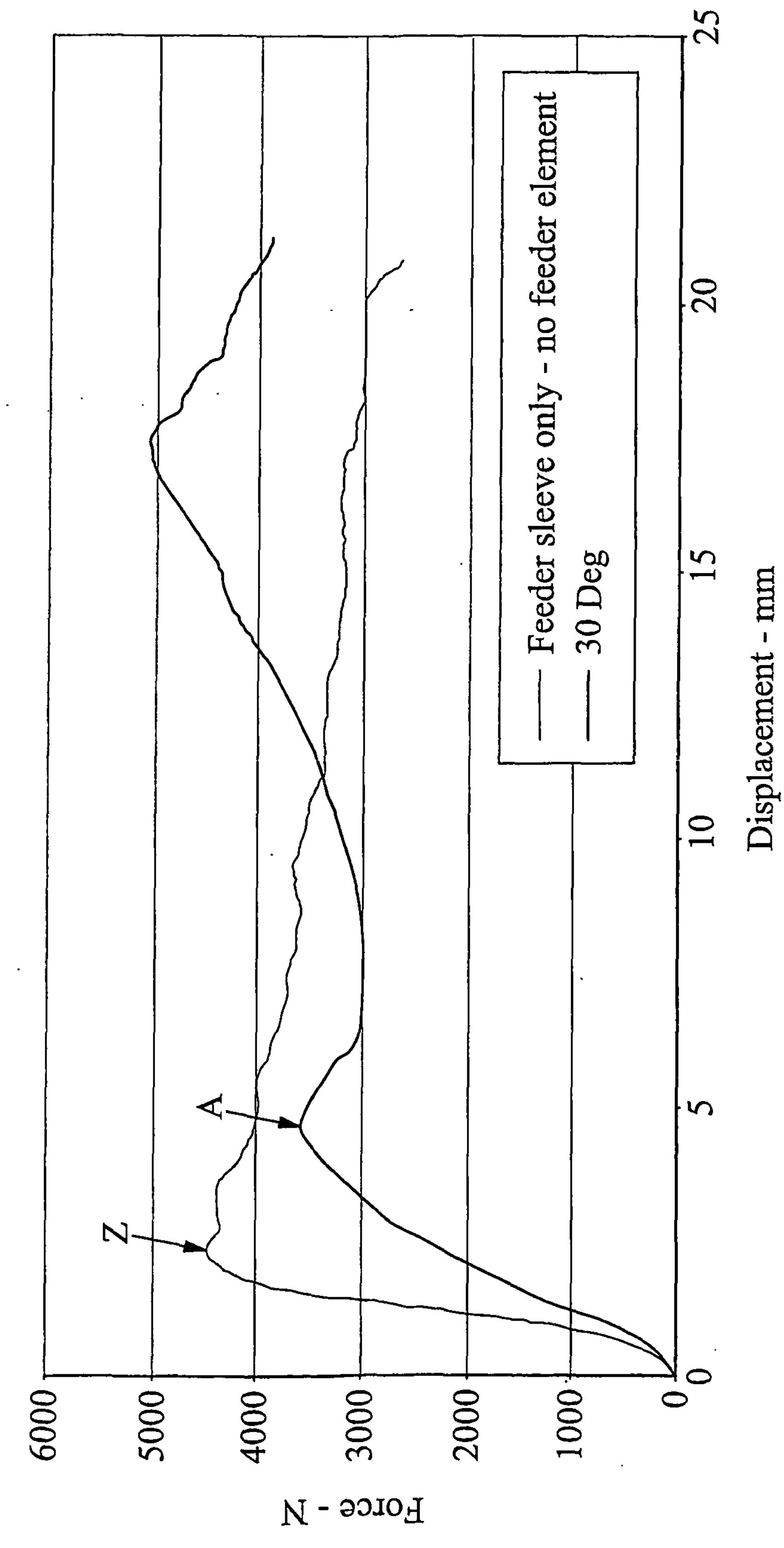
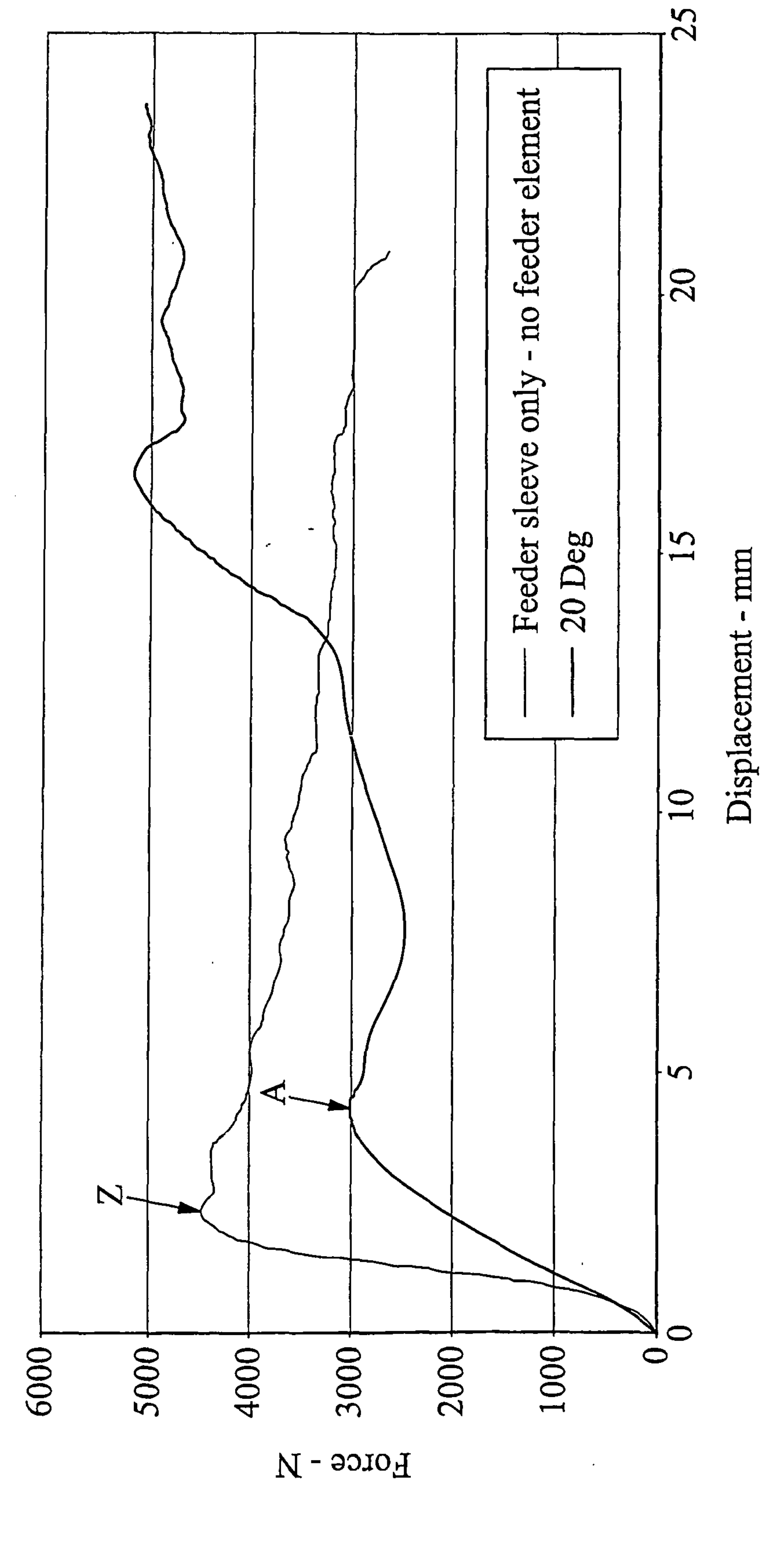


FIG 10i - KALMINEX 2000ZP 6/9 - 20 deg



REFERENCES CITED IN THE DESCRIPTION

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