# 3 Creativity

**Included in this chapter are many of the methods which can be used by individuals or groups in order to increase their creativity and obtain potential solutions to problems. These methods are illustrated by examples and include lateral thinking, avoiding 'set', inversion, analogy, empathy, fantasy, free-wheeling, brainstorming, morphology and synthesis. The chapter finishes with presentation techniques for concepts, illustrated by the on-going example of the seat suspension mechanism.**

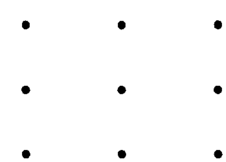
## 3.1 Introduction

Having made a thorough identification of the problem and written a PDS defining the boundaries of that problem, however incomplete, the next stage in the design process involves exploring these boundaries. This is the divergent stage of the design process and involves the generation of as many concepts as possible with the potential for solving the problem. This is the most creative stage of the design process and the techniques described can be applied equally well to both completely new product concepts and to those which only involve development of existing designs.

Society develops rules of behaviour which are considered normal and with which most adults readily conform. In general, education systems, right from the earliest stages, encourage conformity and discourage creativity and invention. Pre-school children have vivid imaginations which are often suppressed by rules such as those of mathematics and language. We were all potential entrepreneurs at the age of four! It is commonly academic success in the application of vertical thinking, particularly in mathematics and science based subjects which leads eventually to engineering as a career. Perhaps more worryingly we are taught in the numerate subjects, such as mathematics and the sciences that most problems have one unique answer. In engineering this is seldom, if ever, the case and in design we are continually searching for an optimum or compromise solution.

Vertical thinking is best explained by means of an example. Consider the story of how monkeys are caught by burying a narrow mouthed jar of nuts in the ground. A monkey comes along, sees the jar, puts its paw into the jar and grabs a handful of nuts. The mouth of the jar is of such a size that it admits the unclenched and empty fist but is not sufficiently large for a clenched fist full of nuts to be removed. The monkey is unwilling to release the nuts and is therefore trapped. With vertical thinking the obvious way of looking at a situation is grasped, perhaps because it has proved useful in the past. Once it is grasped there is a reluctance to let go. The suggestion is not that vertical thinking must be avoided but that it must be complemented by an attempt to escape from a particular way of looking at a situation.

Such vertical thought processes are essential in most engineering specialisms and discipline is essential in detail design work where limits and fits, drawing standards and analysis rules must be followed. However, the basic thought process employed in generating ideas during the concept stage should be that of lateral thinking. In vertical thinking information is used for its own sake in order to progress to a solution, whereas in lateral thinking, information is used, not for its own sake, but provocatively to bring about repatterning. The main purpose in employing lateral thinking is to challenge all assumptions and to try and restructure any pattern. General agreement regarding the continued validity of any assumption is no guarantee that it is correct. It is historical continuity that maintains most assumptions, not a repeated assessment of their validity. Consider the following problem.



Nine dots are arranged as shown. The problem is to link up these nine dots using only four straight lines which must follow on without raising the pencil from the paper. (The answer is at the end of the chapter.)

The implication of the foregoing is that personal creativity can be improved by forced application of techniques such as lateral thinking. However, some limitations must be admitted since heredity, environment and past education impose restrictions on inventive ability. Also, for design engineers, creative ability depends to a large extent on a thorough knowledge of scientific and technical principles. Having accepted these limits it is undoubtedly true that creative ability can be improved by the application of the techniques described. These techniques are proven, but their successful use requires effort and practice.

Anything which improves creativity, such as doing cryptic crossword puzzles, playing chess or attempting creative growth games is to be encouraged. As an example, how many answers are there to the question what is half of thirteen? I propose six and you may be able to think of more. In creative problem solving, it is more important to look at the problem from different vantage points rather than run with the first solution which comes to mind. The six answers to half of thirteen can be found at the end of the chapter, with explanations.

Psychologists have many scales with which they categorize people into types. One such scale is the judging–perceptive scale. At one extreme is the judging person who when confronted with a new situation quickly judges it good, bad or how it ought to be. Specialization tends to bring this about. The expert is a person who within a certain field is best qualified to distinguish right from wrong and good from poor. At the other end of the scale lies the perceptive person who is more concerned with how things are and how they work. To become more creative a person should practice being less judging and more perceptive. A course in art is very helpful in increasing visual perception. Improving perceptiveness requires continual reminding at first since it really involves a change in personality, but it can be done.

One sure way of improving engineering creativity is to carry a note pad everywhere and to sketch any interesting features of existing products which you come across. Where observation is concerned chance favours the prepared mind!

Creativity can be improved, but only with hard work and concentration. The motivation must be to succeed and the working environment must be so arranged that creative thought is encouraged. According to Eddison, invention is 95% perspiration and 5% inspiration. Eddison should know since he is claimed to have tested over 6000 materials before discovering a particular species of bamboo suitable for the filament of an incandescent lamp.

In an effort to define the creative process several inventive people were asked to review their own behaviour. A summary of these descriptions gives the creative process as:

- *Preparation:* information gathering, formulation of the problem
- *Concentrated effort:* application of creativity techniques
- *Withdrawal:* period of mental rest/incubation away from the problem
- *Insight:* the concept which is the solution
- *Follow through:* generalizing and evaluating

Time for creativity is generally not planned in manufacturing companies because schedules have to be met and products launched into the market place as quickly as is possible. However, if inventive solutions are expected then work must be planned so that the inventive process may flourish. More particularly, the period of withdrawal identified as most important by the people canvassed must be positively encouraged.

There is another reason why more time and resources should be allocated to the early design stages and this is illustrated in Fig. 3.1(a) and (b). The graph in Fig. 3.1(a) shows a

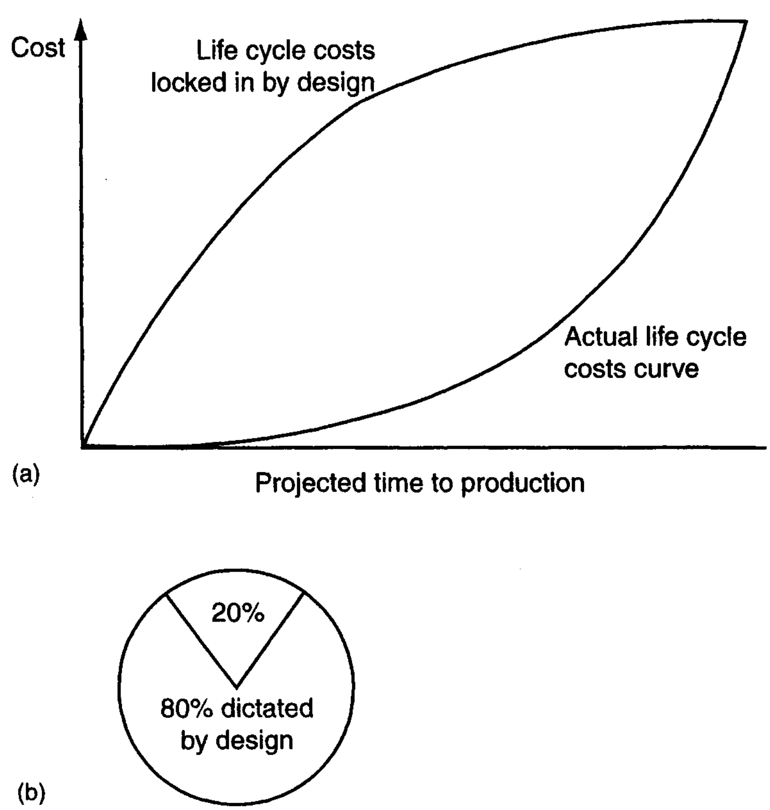



**Figure 3.1(a)** Life cycle cost curves. **(b)** The cost locked in by design

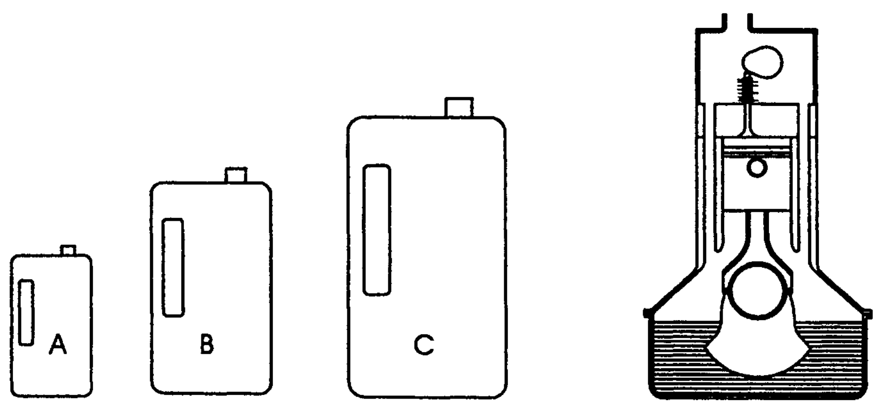
typical product cost to production curve over, for example, four years. The manufacturing costs locked in by design rise steeply in the very early stages. However, the actual costs incurred by the company, illustrated by the lower curve, show that very few resources are applied until much later in the project.

Extra time allowed during the design stages of a project is invariably rewarded since, as illustrated in the pie chart of Fig. 3.1(b), approximately 80% of the cost of manufacturing a product is locked in during these early stages. Any remedial action taken after the design is finalized and production runs begun can only have a minimal effect on manufacturing costs and profit margins.

It is almost always the case that during the creative stage questions will arise which will necessitate alteration or extension of the PDS. These points should be noted immediately and a new issue of the PDS created.

## 3.2 Psychological 'set'

Probably the single most important obstacle to inventiveness is what the psychologists call 'set'. This means a predisposition to a particular mode of thought. To illustrate 'set' the reader is asked to solve the problem shown in Fig. 3.2. Let us assume that engine oil is




| *Problem* | *A* | *B* | *C* | *Desired* | *Answer* |
|---|---|---|---|---|---|
| 1 | 5 | 7 | 10 | 8 | C – B + A |
| 2 | 21 | 23 | 26 | 24 | |
| 3 | 6 | 19 | 25 | 12 | |
| 4 | 7 | 10 | 18 | 15 | |
| 5 | 6 | 8 | 11 | 9 | |
| 6 | 2 | 6 | 10 | 6 | |
| 7 | 8 | 10 | 13 | 11 | |
| 8 | 9 | 23 | 18 | 4 | |
| 9 | 17 | 34 | 34 | 14 | |
| 10 | 14 | 28 | 23 | 9 | |

**Figure 3.2** Problems to illustrate set thinking. For each problem, what is the simplest way to obtain the desired quantity, using full oil cans?

supplied in three different sized containers, A, B, and C, that no partial volumes are marked on the containers and that the same sizes of empty containers are available. Exact quantities are to be used to fill the engine with oil to a desired, though unmarked, level. There are ten problems and as an example problem 1 has been solved. The desired volume of 8 units can be achieved by pouring A into B until B is full, pouring the residue of A into the engine and adding C, i.e. A – B + C. The reader should now attempt to solve the remaining problems as quickly as possible. The answers are to be found at the end of the chapter.

Being 'set' on a particular method or solution is either developed by habit or part of personality. Perseverance, which is generally to be admired, can easily become stubbornness! In such cases the aim can become to make a particular solution work rather than investigating alternatives. In critical situations, old methods are clung to more and more. Familiarity encourages 'set', which is one of the main reasons for the increasing use by companies of outside consultants. Outside consultants are not bound by previous knowledge or history, can challenge traditional approaches and provide a fresh mind in the solution of the problem.

'Set' also affects learning. Some things have to be believed to be seen! Many experiments clearly show that people learn more facts which support their opinions than they do facts which contradict these opinions.

Consider the example of a hot water bottle used for warming a bed. For many years the design has remained 'static', except for the use of better materials as they were developed. The main problem, the potential for leakage causing either a scalded foot or wet bed, has been largely solved by more and more ingenious stoppers. However, it may be that the very name of the product has inhibited radical development. Engineering designers have to be very aware of traditional approaches and question what the customer requires. In this case it is simply a device to warm a bed. Water need not be used nor is a bottle necessary. A questioning approach recently led to the development of a sealed gel-filled bag which is warmed in a microwave oven. This neat solution overcomes all leakage problems but could only stem from overcoming 'set'.

Such a questioning approach led to the design of the JCB Fastrac shown in the photograph of Fig. 3.3 along with a traditional farm tractor, Fig. 3.4. Market analysis showed that a farm tractor spends most of its working life towing trailers along roads and not working in the fields. Traditional tractors are designed for working in the fields not road work. The

**Figure 3.3** JCB Fastrac (Reproduced with kind permission of JCB)

**Figure 3.4** Traditional farm tractor

Fastrac is designed to travel at road speeds, so as not to hold up the traffic, as well as to be 30% faster when tilling the land. This is achieved by even weight distribution over four equally large wheels and a unique suspension system. History alone will reveal the level of success of this radical new design.

## 3.3 Inversion

This is a deliberate method for breaking out of 'set' thinking which involves viewing a problem from a different angle or stand point. If we are looking at a problem externally then forced consideration from the inside is inversion. The use of the following words, and many more, has been shown to stimulate ideas:

| | | | |
|---|---|---|---|
| Adapt | Expand | Magnify | Re-arrange |
| Modify | Reduce | Reverse | Substitute |

An example of reversal is Aesop's fable of the water in the jug which was at too low a level for the bird to drink. The bird tried in vain to obtain a drink but could not succeed as long as he only considered taking water out of the jug. Once the situation was reversed and he thought of adding something to the jug the solution was obvious. He dropped pebbles into the jug until the water level rose sufficiently for him to drink.

A similar story concerns an experimental machine for coal mining applications. The machine operated for two months without any problems. Then it was noticed that the bucket on the machine, which was lifted by hydraulic ram, would not lift the required load. A team of development engineers was initially baffled as to the cause of the problem. Then they looked in the hydraulic tank, which the sight glass indicated was full, and found it almost full to the top with coal. The instruction on the tank said maintain the level of hydraulic oil at a particular level, and because it was almost a five mile trip back to the oil store at the pit head, the machine operator had added rocks, much like the bird, to maintain the level. Obviously this caused the loss of power and emphasizes the need for operator proof design and clear and unambiguous instructions.

An example of inversion applied to engineering design concerns a cab for a new earth-moving machine. Every new design of cab has to meet strict Falling Objects Protection (FOPS-ISO 3449) and Roll Over Protection (ROPS-ISO 3471) standards. These standards set out tests for a cab, during which no part of the frame must encroach on the driver envelope. As shown in Fig. 3.5(a) the particular cab in question failed one part of the test, that where a large weight is swung at the top edge of the cab. The cab failed mainly because the fixings holding the cab to the machine base sheared off and the cab moved bodily sideways.

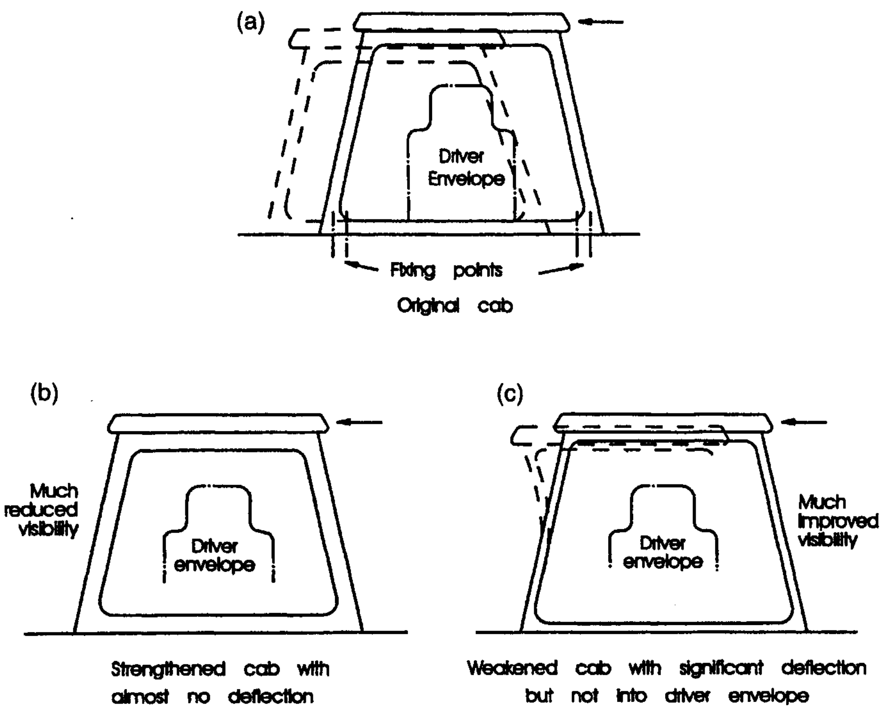



**Figure 3.5** Cab deflection during testing

The instinctive reaction was to re-design the cab with strengthened sections and fixings. This was very disappointing since it was inevitable that visibility would be restricted by more metalwork and less glass. However, careful study of the mode of failure and the use of inversion suggested there was an alternative course of action. Instead of strengthening the cab it was suggested that it was already too strong and that the problem during the test was that the loads were transmitted through the frame directly to the fixings. If the frame was weakened this would absorb some of the load by deflection and lessen the load on the fixings.

The scheduled launch of the machine could not be put back without severe financial losses so it was critical that a new cab was designed and tested quickly. Two new cabs were designed. The first with large gussets in the corners, larger fixings and stronger sections as illustrated in Fig. 3.5(b), and a second cab with weaker sections as in Fig. 3.5(c).

Both passed the test and the weaker design with considerably better visibility and lower manufacturing costs went into production.

## 3.4 Analogy

Another way of generating concepts is to break down a problem into small parts and then consider analogous problems and their solutions from either within engineering or outside. One example of this would be the application of basic kinematic principles to the solution of mechanical design problems. This could be accomplished by studying a list of standard mechanisms to ensure that no good solutions are overlooked. Once a mechanism or linkage is selected to serve as the foundation for the device, features can be added or adapted to meet the constraints of the particular problem at hand.

To use analogy we must develop a thorough knowledge of the way things work generally and have an understanding of other disciplines such as biology, physiology and psychology. One often very fruitful analogy when designing machinery is to imagine how a person would perform the task and attempt to emulate this in the design. This could also be termed employing empathy for problem solving, since empathy involves becoming the part and seeing things as the item or artefact we are considering.

A further useful source of ideas comes from analogy with nature. Nature is a powerful solver of a wide range of problems and many modern engineering inventions replicate nature. For example, consider the following:

- As a bat flies (Fig. 3.6) it emits sharp cries which bounce off obstructions and warn the bat of their position. In other words the bat uses *sonar*. The bat sonar is an amazing discriminator: in a bat-swarm, in cave or night air, a bat can know its own sound among thousands of mobile neighbours, detecting its own signals even if they are 2000 times fainter than background noises. It can 'see' prey, such as a fruit-fly, up to 30 metres away by echo-location, and can catch four or five in a second. This whole auditory system weighs a fraction of a gram! Gram for gram, watt for watt, it is millions of times more efficient and more sensitive than the radars and sonars contrived by man.
- To jet-propel itself for a high-speed swim, the squid (Fig. 3.7) sucks water into its body, then shoots the water out of a tube under its head. The squid uses jet propulsion.
- The idea of producing a flying machine that spins was originally thought of many thousands of years ago in China when a toy based on a flying top was produced. This idea probably came from watching sycamore seeds fall from the trees.
- The caribou has wide feet, or snow shoes.

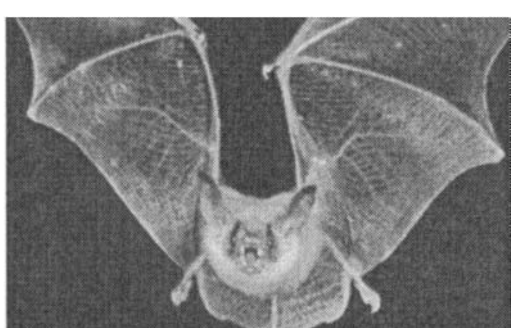


**Figure 3.6** Bat in flight

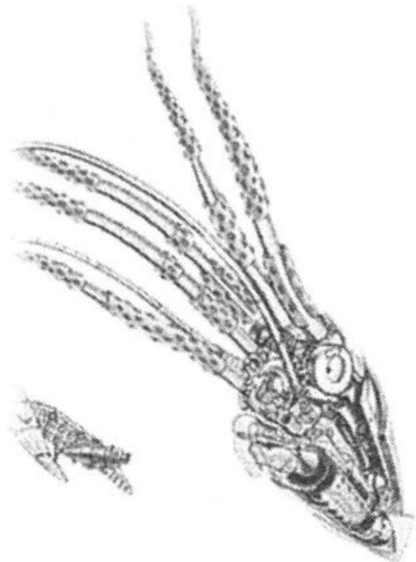


**Figure 3.7** Squid swims by jet propulsion

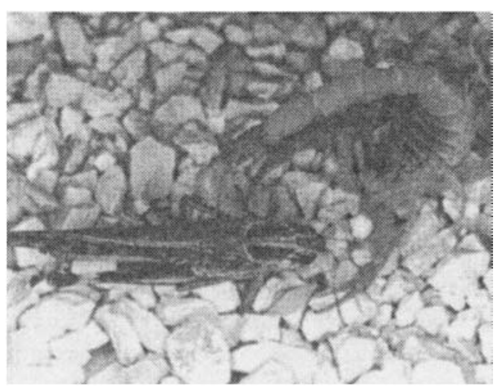


**Figure 3.8** Scorpion with sting in tail

- The scorpion (Fig. 3.8) applies its sting through a device which we now know as a hypodermic needle. Here the scorpion is injecting a locust.
- When biting, a snake applies an anaesthetic which lessens the pain of the victim. This principle has only relatively recently been used for operations.
- Sea snails cling to rocks by means of suction. Suction cups are in wide use today.
- Birds brake with their tail feathers just as planes do with flaps.

## 3.5 Fantasy

Insight into the truly creative thought processes can be gained from a study of modern and classical literature. Those with fertile minds, such as Wells, Huxley, Clarke and Asimov, are well known for their projected visions of the future. Many inventors have used ideas contained in these science fiction books to bring about a solution to an intractable problem.

As specific examples consider *20,000 Leagues Under the Sea* by Jules Verne (1870) and *Frankenstein* by Mary Shelley (1818). In the first the then almost unheard of submarine is extended into the sophisticated device roaming the seas of the present day. Perhaps more inventively that submarine had electric lighting and the book contained quite a detailed section covering the chemical oxygen production necessary to keep the craft submerged for long periods. In the second, the notion of electric charges giving life is introduced, in much the same way as electric shock treatment of cardiac arrest victims is used by medics today.

What is being suggested then is that a study of the more modern writers of science fiction could provide an increased understanding of the creative process and may even reveal potential inventions in the making. One worrying prediction concerns *I, Robot* by Asimov (1950) where robot brains program themselves into the position of absolute master!

## 3.6 Technological advances

Many 'scientific' advances are made each year which affect the work of engineering designers and provide exciting opportunities for product improvement or the introduction of new products. As an example, new materials are being developed almost daily. Thus, it is essential that professional engineers engage in some form of Continuing Professional Development (CPD), such as reading trade magazines and attending updating courses.

Consider the humble vacuum cleaner. This was, to all intents and purposes a fully developed or 'static' product. Then along came the application of new technology and

**Figure 3.9** Dyson Dual Cyclone vacuum cleaner (Reproduced with kind permission of Dyson Appliances Ltd.)

materials, in the shape of the Dyson, illustrated in the photograph of Fig. 3.9. The Dyson vacuum cleaner has Dual Cyclone filtration and many other patented design features. The main advantages claimed over conventional vacuum cleaners are that no bag means 100% suction, 100% of the time and no bag odour. The vacuum cleaner has the largest electrostatic filters found on any vacuum cleaner, is designed to sit on the stair, has integral tools, the large rear wheel/small front castor design of the Dyson makes it easy to manoeuvre around corners. The body of the Dyson Dual Cyclone is made from ABS and polycarbonate.

## 3.7 Brainstorming

The problems faced by engineering designers are many and varied, ranging from those necessitating radically new solutions to the everyday problems such as oil seal, bearing and gear design or selection. The full range of problem types can benefit from the application of techniques which are often categorized as 'organized ideation', such as Brainstorming.

Brainstorming involves attacking a problem with the full creative power of the brain and is normally a group activity. The basic principle is that of association of ideas. Everyone has experienced the situation where an idea voiced by someone else brought a thought to mind or where a word spoken during a conversation makes you think of something that would never have come to mind otherwise. In other words ideas are stimulated by the ideas put forward by others.

Brainstorming as a technique was first suggested in *Applied imagination* by Alex F. Osborn (1953) as an alternative to the more usual business meeting. He regarded such meetings as a waste of time since they often did not yield anything of value. Osborn set out four rules to be observed by a group discussing a problem:

***Criticism is ruled out*** Evaluation and criticism of ideas at this stage must be avoided since it inhibits the production of ideas. Even the wildest idea can have some usefulness. The major inhibitor to successful brainstorming is one of attitude and all judgement must be deferred.

***Freewheeling is wanted*** Give free rein to thoughts and creative imagination.

***Quantity is wanted*** The basic premise here is that quantity breeds quality. The more concepts that can be produced the more likely it is that a good solution will be found.

***Combination and improvement are sought*** After the initial flood of ideas each is examined to ensure that the underlying principle is clearly identified. More ideas may emerge as a result. Where possible ideas are combined.

During a brainstorming session all suggestions and ideas are recorded. This is done until many ideas have been collected and current thinking suggests that not until 70 concepts have been generated should the process be halted. Recording ideas as they arise means that the memory is not being relied upon, the mind remaining uncluttered and free to produce additional ideas.

The optimum duration of a brainstorming session is half an hour, with most useful ideas being suggested in the second quarter. Normally in a session, individuals are free to contribute at any time but when a group is over six in size this is not practical. Stein, in his excellent text, *Stimulating Creativity*, favours sequential brainstorming for all relatively large groups. During this the group members sit in a circle and every member in turn puts forward one idea or suggestion.

One further variation of brainstorming technique is worthy of mention since it has proved most fruitful when used by students of engineering design. This is a forced creativity exercise in which the group as a whole is subdivided into groups of three. Everyone considers the same problem and must write down a suggested solution in one sentence or simple diagram in one minute. The papers are folded to hide the first solution and then passed around the smaller groups twice and new solutions written down. Each piece of paper contains six ideas and there are the same number of papers as participants. Therefore many different ideas can be generated in little over six minutes. There are of course many permutations on this theme.

Many companies are now introducing total quality management procedures and as part of this process hold regular brainstorming sessions. The personnel involved in these meetings are not limited to design staff, nor indeed to technical staff. All staff are considered valuable in the process of generating concepts and design engineers must accept this fact for the overall good of the company.

## 3.8 Morphological analysis

When a device or system being designed must satisfy several functions or combine several features it is worth subdividing the problem. Concepts are then generated to satisfy each smaller problem area and then later combined. In order that every potential combination of these concepts is considered then a morphological analysis should be carried out and a morphological chart drawn up. A four stage approach is recommended.

(1) Make a close examination of the specification and list the functions and features which are required.
(2) Identify as many ways as possible of providing each feature or function.
(3) Draw up a chart with the essential features or functions on the vertical axis. Along each row enter the means of achieving each of the functions or providing each desirable feature.
(4) Identify all practical combinations which satisfy all requirements of the whole.

Morphological analysis is best illustrated by means of a case study. Consider, as an example of morphological analysis, the problem of digging small trenches. These trenches could be required for various reasons; drainage channels in a large lawn or playing field or for carrying services on a new housing estate, for example. The problem is to design a new device, a mini-trencher, which would dig a relatively shallow trench more cheaply and quickly than two labourers using spades. Taking the four steps as outlined we must first list the essential features:

- support preventing sinking in soft ground;
- provide forward motion;
- type of power source;
- excavating mechanism used;
- power transmission system;

- stopping the mini-trencher;
- spoil removal to side of trench;
- position of the operator if required.

In the next step alternative concepts are generated for the provision of each feature. Each full or part concept may be presented as a simple sketch or in words, depending on the complexity of the concept. In this case the concepts generated for the sub-problem of excavating mechanism are back hoe, plough, auger, dredger type buckets and wheel with buckets. All other requirements were considered in a similar manner and a morphological chart created with the concepts generated along the horizontal axis, as can be seen in Fig. 3.10.

| *Feature* | *Solutions* | | | | |
|---|---|---|---|---|---|
| Support type | wheels | tracks | skis | ***balloon tyres*** | |
| Forward motion | drive wheels | ***single wheel drive*** | tracks | spiked wheel | manual |
| Power source | ***petrol*** | diesel | electric | bottled gas | manual |
| Excavating mechanism | back hoe | plough | auger | ***dredger buckets*** | wheel buckets |
| Power transmission | hydraulic | chains | belts | ***gears and shafts*** | |
| Stopping trencher | brakes | dead man's handle | clutch | ***torque limiter*** | |
| Spoil removal | chute | auger | ***plough*** | conveyor | |
| Operator position | seated at front | seated behind | ***walking behind*** | remote control | |

**Figure 3.10** Morphological chart for mini-trencher

All that remains is to identify all the possible combinations of features which may satisfy the overall requirements. As will be self-evident an almost infinite number of 'new ideas' could be generated by such an analysis. The sketch in Fig. 3.11 represents the combination identified on the morphological chart of Fig. 3.10 by the emboldened and italicized ideas. That is balloon type tyres, single drive wheel, petrol engine, ladder boom with dredger type buckets, gear box transmission, torque limiter, plough spoil removal and operator walking behind. It is likely that this would be one of the preferred options but the selection procedures contained in Chapter 4 should be used to confirm this.

## 3.9 Presentation

The three-dimensional sketch of the mini-trencher in Fig. 3.11 is far too detailed for the form of presentation necessary at the concept stage. Indeed, too much detail is counter

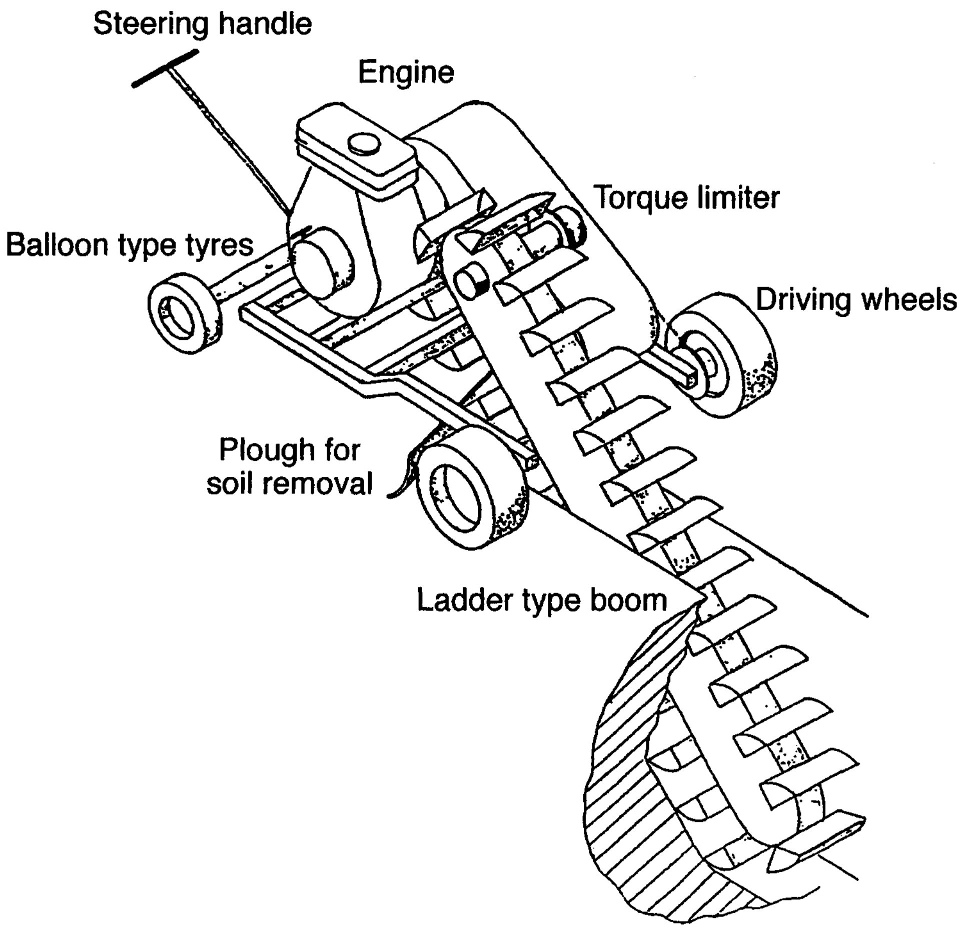



**Figure 3.11** Concept sketch for trench digger

productive since it can detract from the working principles of the concepts. The selected concept is refined and detailed at a later stage, but most of the effort in developing each design beyond simple sketches is wasted since the majority of concepts will be discarded.

What is very important when presenting concepts is that each concept generated is given equal importance by using a standard form of presentation. The form recommended is that of concept sketches or line diagrams. In many engineering disciplines standard symbols have been developed, particularly for circuit diagrams. Hydraulic and pneumatic components, electronic components and mechanical components all have standard simplified representations.

Consider the seat suspension mechanism problem for which a specification was written in Chapter 2. Many concepts were generated and sketched and after employing the concept generation techniques contained in the current chapter along with the combinational methods described the overall concepts shown in Fig. 3.12 were produced. Six only are illustrated since by inspection the other concepts had serious and obvious deficiencies making them impractical. These concept sketches are sufficient for concept selection purposes and should be accompanied by explanatory notes as necessary.

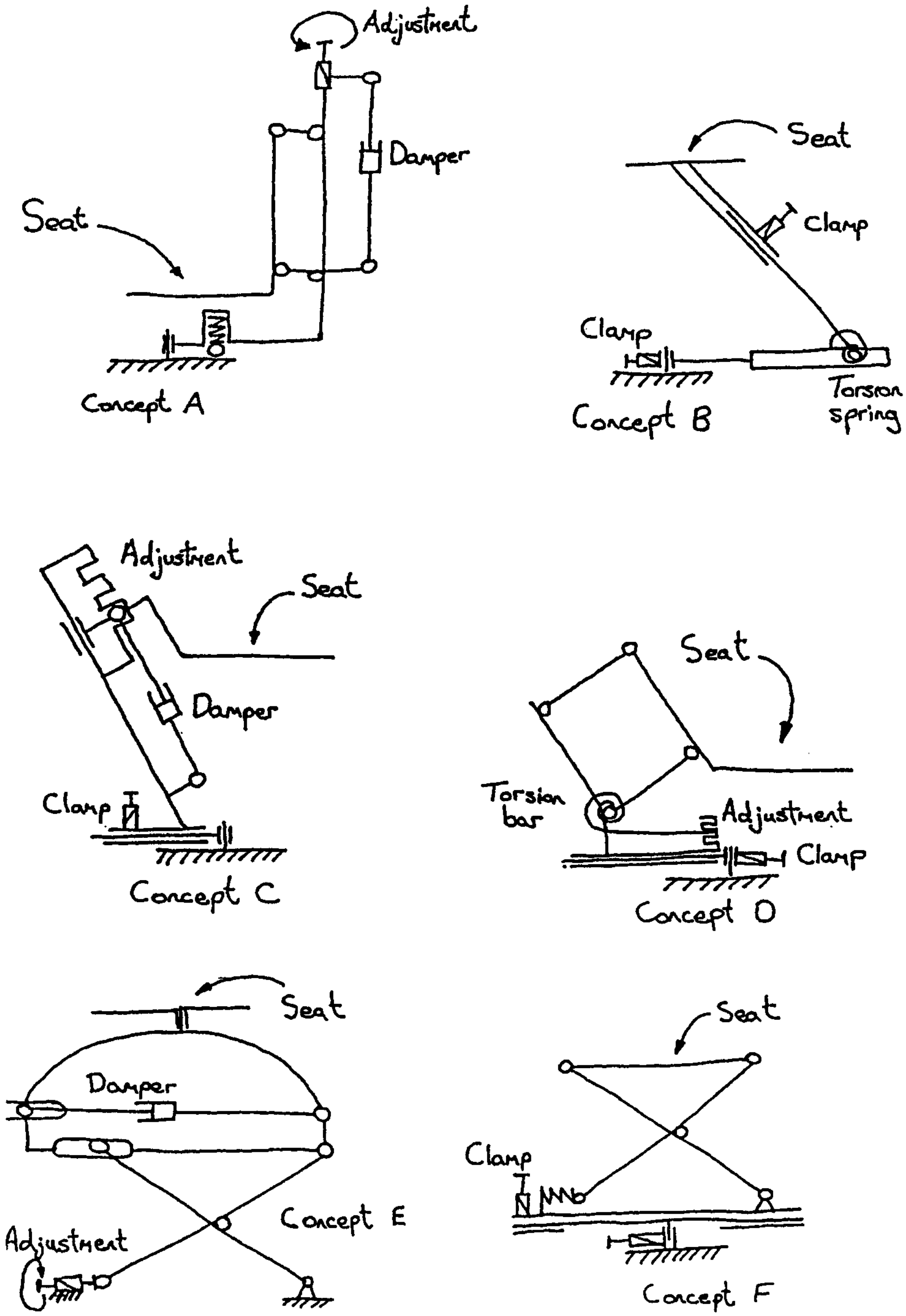
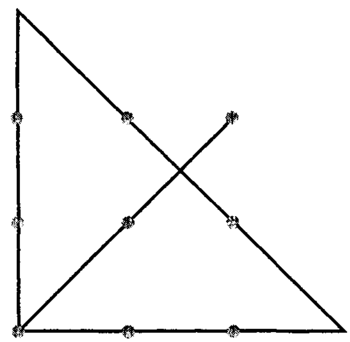



**Figure 3.12** Concept sketches for seat suspension mechanism

## 3.10 Answers to problems

1. The nine dots can be joined as shown. The false assumption usually preventing you from obtaining a solution is that the straight lines must link up the dots without extending beyond the boundaries set by the outer lines of dots. This restriction, whilst often assumed is not stated in the 'design brief' or 'problem specification'. Assumptions, tradition and hearsay should always be questioned.



2. What is half of thirteen?

6.5 is 13 divided by 2. 13 consists of a 1 and a 3. Therefore 1 and 3 both make up half the number 13. In roman numerals 13 is written XIII. A horizontal line dividing the letters in half reveals VIII on top, which is 8. XIII divided vertically in half gives XI/II so both 11 and 2 are half of thirteen.

The answers are 1, 2, 3, 6.5, 8, 11.

3. If in the engine oil pouring problem you obtained the answers for all problems of A – B + C then you were a victim of 'set'. However, if you obtained the correct answers to 6, (B) and 10, (C – A) and you solved the nine problems in under 2 minutes then you were not 'set' by the other answers. It is interesting to note that if the problem was inverted and worked from the bottom up then correct answers would be obtained more readily.

## 3.11 Principles

### *Concepts generation principles*

***Divergence*** The concept stage of the design process begins with the generation of many potential solutions by broadening of the problem.

***Creation*** Many potential concepts are created by teams using such methods as brainstorming.

***Inversion*** Different concepts can often be created by the simple technique of looking from a different angle. For example, imagining yourself to be the device to be designed.

***Analogy*** Nature in many forms has solved problems and the methods employed can often be modified in the solution of engineering problems. Personal analogy is a powerful technique.

***Fantasy*** In this technique the imagination runs free and concepts are accepted without criticism. 'Freewheeling' is sought.

***Combination*** Having created many concepts, the possibility of combining aspects of these concepts to create an optimum solution is investigated.

***Observation*** Creative people take regular note of their surroundings and are more perceptive than average.

***Gestation*** The creative process, following a period of concerted effort, requires a period of withdrawal from the problem.

***Iteration*** During the generation of concepts it is inevitable that the boundaries of the PDS will be questioned. Earlier stages of the design process may need to be revisited.

## 3.12 Exercises

1. Your company has just bought the salvage rights to the wreck of the *Titanic* as a speculative venture. The wreck is lying at a depth of approximately 2 miles, is standing on end and at a pressure of 300 bar and temperature of 4°C. Use group brainstorming techniques to generate concepts for raising the *Titanic*.

2. Blind people have difficulty in filling receptacles with hot liquids to the required level. Problem areas are the water level in a pan when cooking, liquid levels in a cup and the level of water in a bath. Generate as many concepts as possible for a simple hand-held device which will indicate to the person the level of liquid in all these cases.

3. Generate concepts for replacing the traditional type of scarecrow with alternative methods of bird scaring.

4. As crime figures mount, fear of strangers coming to the door, particularly at night, leads to many people refusing to open the door unless they are sure who is calling. A security chain is good, but could quickly be snipped through with bolt cutters. Remote TV surveillance and electronically operated locks are relatively expensive. Using group brainstorming techniques generate as many concepts as possible for the design of a simple low-cost means of preventing a front door from opening fully which can be easily and quickly disengaged if the caller turns out to be a friend.

5. Within a large catering organisation many slices of bread are buttered. This is a tedious and time consuming task. Generate six concepts for automating the process of applying the butter to the bread.

6. Using the techniques explained generate as many alternative concepts for solving Exercises 3: can opener, 4: vaciron, 6: multi-gym, 7: rail-cutter and 8: bilge filter which were outlined at the end of Chapter 2.