MANUFACTURING ENGINEERING TRIPOS PART I

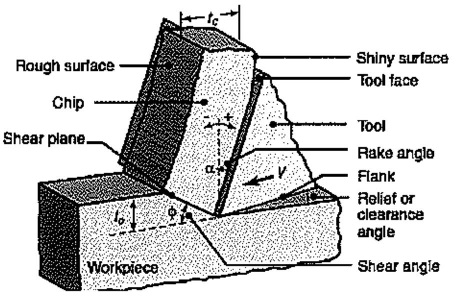
Monday 2 May 2011 9 to 10.30

PAPER 2

Module 3P2: PRODUCTION MACHINES AND SYSTEMS (CRIB)

Q1)

(a) Chip formation in metal cutting is accompanied by substantial shear and frictional deformations in the shear plane and along the tool face; The cutting itself is a process of extensive plastic deformation to form a chip that is removed afterward. The basic mechanism of chip formation is essentially the same for all machining operations. Assuming that the cutting action is continuous, we can develop so-called continuous model of cutting process shown in the figure:



Cutting is performed with a cutting tool moving at a cutting speed V in the direction of primary motion. The cutting tool is inclined at the rake angle, α. The rake angle can be positive, zero, or negative, typically taking values from +150 to -60. The rake angle influences significantly the process of plastic deformation in cutting and therefore the chip thickness, cutting forces and temperatures. The tool is set to remove a cut with thickness t_o and width t_d . In the simplest model of orthogonal cutting, the plastic deformation takes place by shearing in a single shear plane inclined at the angle ϕ (shear plane angle). The produced chip has a thickness of t_c (chip thickness), and moves at speed V_c .

(b) At low cutting speeds, energy is dissipated in the shear plane and at the chip-tool interface, and conducted through the workpiece and/or tool and eventually to the environment. At higher speeds, conduction cannot take place rapidly enough. At even higher speeds, the chip will carry the heat away, hence the workpiece will remain cooler. This is one of the major advantages of high speed machining.

(c) Continuous chips are not desirable because (a) the machines are now mostly untended and operate at high speeds, thus chip generation is at a high rate and (b) continuous chips would entangle on spindles and machine components, and thus severely interfere with the machining operation. Conversely and for that reason, discontinuous chips or segmented chips would be desirable, and indeed are typically produced using chip-breaker features on tools.

(d) There are four types of chips that are commonly produced in cutting,
1. discontinuous chips
2. continuous chips
3. continuous chips with built up edge

4. Serrated, or segmented chips

A **discontinuous chip** comes off as small chunks or particles. When we get this chip it may indicate,

- brittle work material
- small or negative rake angles
- coarse feeds and low speeds

A **continuous chip** looks like a long ribbon with a smooth shining surface. This chip type may indicate,

- ductile work materials
- large positive rake angles
- fine feeds and high speeds

A continuous chip with a built up edge still looks like a long ribbon, but the surface is no longer smooth and shining. When we get this chip it may indicate,

- ductile work material
- small or negative rake angles
- low speeds

A **serrated chip or segmented chip.** When we get this chip it may indicate,

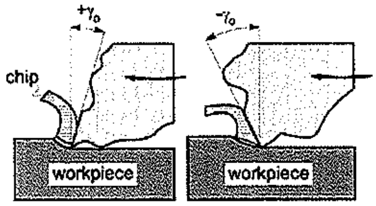
- Semi-brittle work material
- negative rake angles
- low to medium speeds

(e) Although hard and strong in compression, these materials are brittle and relatively weak in tension. Consequently, negative rake angles, which indicate larger included angle of the tool tip are preferred mainly because of the lower tendency to cause tensile stresses and chipping of the tools.

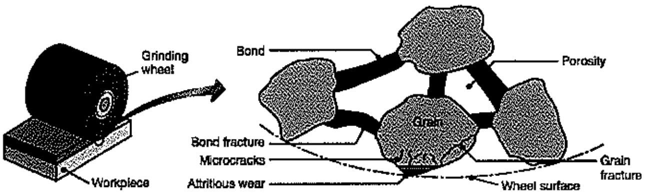
Q2)

a) Grinding wheels are an example of bonded abrasive tools: abrasive grains are closely packed into different shapes, the most common is the abrasive wheel. Grains are held together by bonding material. Abrasive machining process that use bonded abrasives include grinding, honing, superfinishing;

Regardless the form of the abrasive tool and machining operation considered, all abrasive operations can be considered as material removal processes with geometrically undefined cutting edges, the concept should illustrated in the figure such as that given here:



Abrasive machining can be likened to the other machining operations with multipoint cutting tools. Each abrasive grain acts like a small single cutting tool with undefined geometry but usually with high negative rake angle. Abrasive machining involves a number of operations, used to achieve ultimate dimensional precision and surface finish. From the principal abrasive operations, grinding is a very common finishing process. Grinding is a material removal process in which abrasive particles are contained in a bonded grinding wheel that operates at very high surface speeds. The grinding wheel is usually disk shaped and is precisely balanced for high rotational speeds.



A grinding wheel consists of abrasive particles and bonding material. The bonding material holds the particles in place and establishes the shape and structure of the wheel. The way the abrasive grains, bonding material, and the air gaps are structured, determines the parameters of the grinding wheel, which are

- abrasive material,
- grain size,
- bonding material,
- wheel grade, and
- wheel structure.

Wheel wear

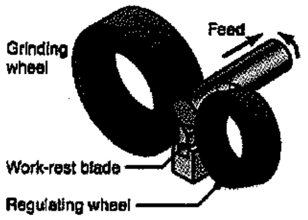
Three mechanisms are recognized as the principal causes of wear in grinding wheels:

1. Grain fracture,
2. Attritious wear, and

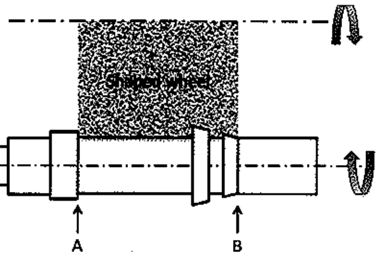
3. Bond fracture.

Grain fracture occurs when a portion of the grain breaks off but the rest of the grain remains bonded in the wheel. The edges of the fractured area become new sharp cutting edges on the grinding wheel. This makes the grinding wheel self-sharpening, a unique property of a cutting tool.
Attritious wear involves dulling of the individual grains, resulting in flat spots and rounded edges. Attritious wear is analogous to tool wear in a conventional cutting tool.
Bond fracture occurs when the individual grains are pulled out of the bonding material. Bond fracture usually occurs because the grain has become dull due to attritious wear and the resulting cutting force is excessive. Sharp grains cut more efficiently with lower cutting forces; hence, they remain attached in the bond structure.

b) Centreless grinding is process for continuously grinding cylindrical surfaces in which the workpiece is supported not by centers or chucks but by rest blades. The workpiece is ground between two wheels, The largest wheel does the grinding, while the smaller regulator wheel which is tilted regulates the axial velocity of the workpiece. Centreless grinding can be carried out internally or externally. Typical parts made by centreless grinding are roller bearings, piston pins, shafts, and similar components. Parts with variable diameters, such as bolts, valve tappets, and distributor shafts, can be ground by Plunge centreless grinding. Sleeve-shaped parts and rings can be ground by the internal centreless grinding, in which the workpiece is supported between three rolls and is internally ground.



c) This operation is best performed with a shaped grinding wheel that matches the profile of the part to be ground. A CNC dressing process is performed on a stock grinding wheel that effectively machines the shape of the required profile into wheel. The component is mounted onto a rotary axis of a machine, held at either end and centred. The shaped grinding wheel is then set to the correct lateral position along the component, it is then set to rotate in the opposite direction to the component, and moved incrementally towards the surface of the component until the desired grinding depth is reached.



There are three basic parameters that influence surface finish.
***Abrasive grain size**: smaller grit size will produce lower surface roughness;*

***Structure**: A more dense structure of the grinding will afftect surface finish, i.e., more abrasive grains per* cubic mm will increase the number of active grains in contact with the work surface thus improving the surface finish;

***Cutting velocity**: The surface finish will be improved by increasing the number of* abrasive grains per unit time, therefore by increasing the cutting speed.

Q4)

(a) Effective asset management delivers value to any organisation from the following perspectives:
  - (i) increase the reliability – this would translate to less breakdowns, higher productivity, and possibly better quality products, etc.
  - (ii) increase the efficiency – improper (or lack of) maintenance may result in degradation in performance, and hence lower output, quality etc.
  - (iii) increase the life of the equipment – especially critical in repairable systems – by better maintenance, the design-life of the equipment can be extended. This can also be done by upgrading various components/sub-systems selectively.
  - (iv) comply with regulations – this is important for safety-critical operations such as petro-chemical industries, and also for other industries
  - (v) "shine" factor – poor maintenance = poor quality = bad customer perception

(b) The following strategies may be suitable for the assets
  - (i) Light bulbs – normally reactive maintenance. However, it might be worth replacing all the light bulbs together depending on the height of the ceiling (which might require setting up of scaffolding etc).
  - (ii) Motor bearing – depending on the criticality of the motor/bearing, you may choose between "fix when it fails" and condition-based maintenance. If CBM is chosen, vibration levels maybe monitored to predict timing of failure.
  - (iii)Cutting tool – depending on the cost of the tool, regular monitoring of wear of the tool is often performed to indicate time of replacement.
  - (iv)Smoke alarm batteries – the batteries are replaced on failure. However due to the criticality of smoke/fire alarms, the condition of the batteries need to be monitored at regular intervals.

(c) Failure rate, λ = 1 failure every 20 days = 1/20 per day = 1/(20 x 24) per hour = 0.002

Assuming failure rate to be constant, the probability that the tool will survive a machining operation that takes 5 hours is the reliability of the tool for 5 hours.

$R(t) = e^{-\lambda t} = 0.989$

(d)

$c(t)$ is the operating cost per unit time at time t after replacement.

R is the total cost of a replacement.

The replacement policy is to perform replacements at intervals of length t_r.

The objective is to determine the optimal interval between replacements to minimise the total cost of operation and replacement per unit time.

$C(t_r)$ = total cost in interval $(0,t_r)$/length of interval

$$\therefore C(t_r) = \frac{1}{t_r}\left[\int_0^{t_r} c(t)dt + R\right]$$

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In this case, $c(t) = a + bt$

$$\therefore C(t_r) = \frac{1}{t_r}\left[\int_0^{t_r} (a + bt)dt + R\right] = \frac{1}{t_r}\left[at_r + \frac{bt_r^2}{2} + R\right] = a + \frac{bt_r}{2} + \frac{R}{t_r}$$

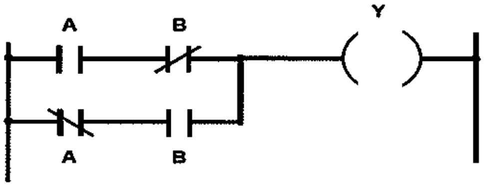
In order to find the optimal solution the time of replacement we need the differentiate the above expression and equate it to zero.

$$\therefore \frac{b}{2} - \frac{R}{t_r^2} = 0$$

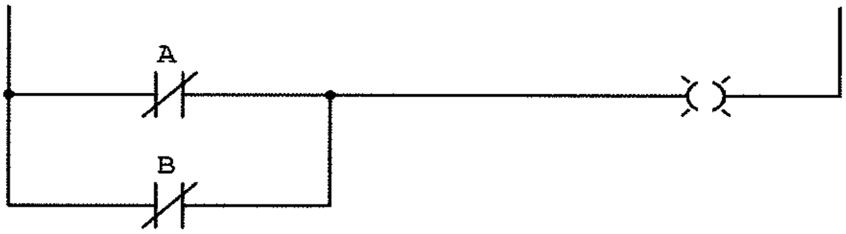
$$\therefore t_r = \sqrt{\frac{2R}{b}}$$

Q3)

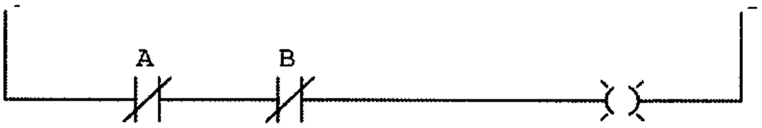
(a) An XOR logic can be implemented in ladder logic code as follows



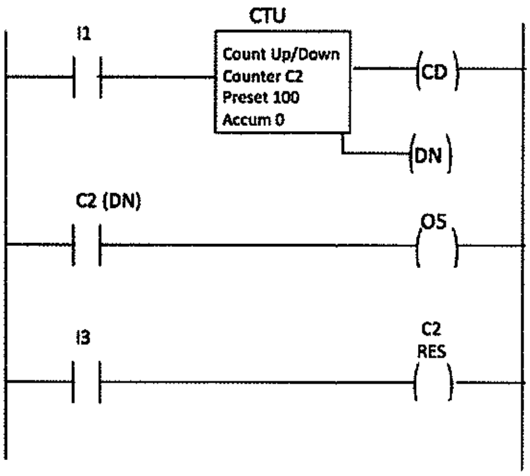
A NAND logic can be implemented in ladder logic code as follows



A NOR logic can be implemented in ladder logic as follows

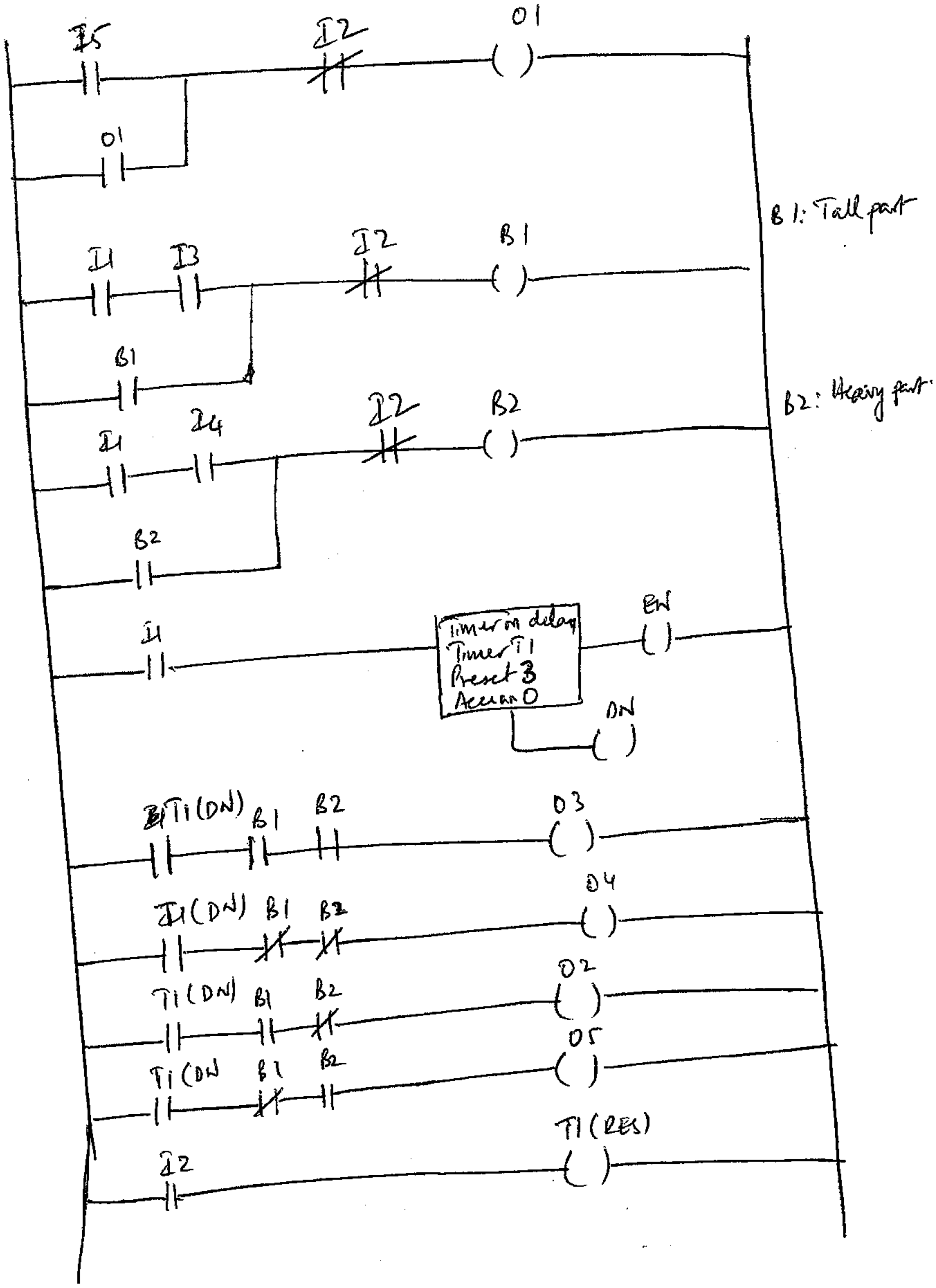


(b)



Upward and downward counters are used to monitor the accumulation of events (e.g. parts passing a particular point). Once the accumulated counter reaches the preset value the rung (DN) becomes "true" or "on" and can be used as an alarm or as part of a resetting sequence. CD indicates that the counter is counting.

3(b)


I5
I2
O1
O1
B1: Tall part
I1
I3
I2
B1
B1
B2: Heavy part
I1
I4
I2
B2
B2
I1
Timer on delay
Timer T1
Preset 3
Accum 0
EN
DN
T1(DN)
B1
B2
O3
T1(DN)
B1
B2
O4
T1(DN)
B1
B2
O2
T1(DN
B1
B2
O5
I2
T1(RES)